MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XLV. FEBRUARY 13, 1885. No. 4.

EDWIN DUNKIN, F.R.S., President, in the Chair.

Rev. Edward Allen, M.A., Castlechurch Vicarage, near Stafford;

Rev. John Burgess, 90 Cheriton Road, Folkestone; and

P. Edward Dove, 9 Argyll Street, Regent Street, W.;

were balloted for and duly elected Fellows of the Society.

REPORT OF THE COUNCIL TO THE SIXTY-FIFTH ANNUAL GENERAL MEETING OF THE SOCIETY.

The following table shows the progress and present state of the Society:—

	Compounders	Annual Subscribers	Non-resi	Mathematical Society	Total Fellows	Associates	Patron	Grand Total
December 31, 1883 ...	226	371	2	3	602	49	1	652
Since elected	+3	+23	...	...	...	+3	...	...
Deceased	−3	−9	−1	...	...	−3	...	...
Resigned	...	−5	...	...	...	...	...	...
Expelled	...	−1	...	...	...	...	...	...
Removals	+1	−1	...	...	...	...	...	...
December 31, 1884 ...	227	378	1	3	609	49	1	659

Mr. Common's Account as Treasurer of the Royal

RECEIPTS.

	£	s.	d.	£	s.	d.
Balance at Bankers', Jan. 1, 1884:	291	9	6			
,, in hand of Assistant Secretary on account of Turnor and Horrox Funds	7	0	2			
,, in hand of Assistant Secretary on Petty Cash account...	10	18	11			
				309	8	7
Half-year's dividend on £7,500 Consols... ...	110	3	2			
,, ,, £5,700 New 3 per cent. Stock	83	14	5			
,, ,, £7,500 Consols... ...	110	3	2			
,, ,, £5,700 New 3 per cent. Stock	83	14	5			
Dividends on £500 Metropolitan Stock	14	14	0			
				402	9	2
Received on account of Subscriptions:						
Arrears	189	0	0			
269 Annual Contributions for 1884 ...	564	18	0			
3 ,, ,, 1885 ...	6	6	0			
22 Admission Fees	46	4	0			
19 First Contributions	32	11	0			
				838	19	0
4 Composition Fees				84	0	0
Sales of Publications:						
At Williams & Norgate's, 1883	28	10	3			
At Society's Rooms, 1884	33	6	3			
				61	16	6
Due to Assistant Secretary on Petty Cash account, Dec. 31, 1884...				4	9	1
				£1,701	2	4

Astronomical Society, from Dec. 31, 1883, to Dec. 31, 1884.

EXPENDITURE.

	£	s.	d.	£	s.	d.
Assistant Secretary: Salary	225	0	0			
„ „ for assistance in editing Society's publications...	50	0	0			
				275	0	0
Income Tax and House Duty				9	3	9
Fire Insurance				7	16	6
Printing: Spottiswoode & Co.	666	3	6			
Engraving, Lithography, &c.	25	0	11			
Computation of Ephemerides in *Monthly Notices*	50	0	0			
				741	4	5
Turnor and Horrox Funds: Purchase of Books for Library	8	12	3			
Binding Books in Library	24	16	2			
				33	8	5
Carpet and rugs for Library				55	19	0
House Expenses	35	3	8			
Wages	26	12	0			
Postage, &c.	58	13	9			
Carriage of parcels, &c.	5	1	1			
Stationery and office expenses	7	17	8			
Expenses of meetings	20	0	0			
Coals and gas	51	4	2			
Sundry fittings, repairs, &c.	8	12	9			
Sundries	4	8	1			
				217	13	2
Lee fund				5	0	0
Mrs. Jackson-Gwilt's annuity				8	19	0
Bankers' commission on cheques					1	0
Balance at bankers', Dec. 31, 1884	338	9	2			
„ in hand of Assistant Secretary on account of Turnor and Horrox Funds...	8	7	11			
				346	17	1
				£1,701	2	4

Audited and found correct, Jan. 7, 1885.

ROBT. J. LECKY.
RICHARD INWARDS.

Assets and present property of the Society, January 1, 1885:—

	£	s.	d.	£	s.	d.
Balance at Bankers', Dec. 31, 1884	338	9	2			
„ in hand of Assistant Secretary on account of Turnor and Horrox Funds... ...	8	7	11			
	346	17				
Less due to Assistant Secretary on Petty Cash account	4	9	1			
				342	8	0
Due on account of subscriptions:						
14 Contributions of 3 years' standing ...	88	4	0			
30 „ 2 „ ...	126	0	0			
60 „ 1 „ ...	126	0	0			
6 Admission fees and first contributions ...	18	18	0			
Due from Messrs. Williams & Norgate for sales of Publications during 1884				38	10	8

£7,500 Consols, including the Lee Fund, the Turnor Fund, and the Horrox Memorial Fund.

£5,700 New 3 per cent. Stock, including Mrs. Jackson-Gwilt's gift (£300).

£500 Metropolitan Board of Works Stock.

Astronomical and other MSS.; Books, Prints, Instruments, and Furniture.

Unsold Publications of the Society.

One Gold Medal.

Report of the Auditors.

We, being two of the duly appointed Auditors, beg to lay before this Annual General Meeting of the Royal Astronomical Society the following Report:—

We have examined the Treasurer's account, and an account of the assets and property of the Society, and have found and certified the same to be correct.

The receipts and expenditure for the past year are as stated in the Treasurer's account. The cash in hand on December 31, 1884, including the balance at the bankers', amounted to 346*l.* 17*s.* 1*d.*

The funded property is the same as at the end of last year.

The books, instruments, and other effects have been examined and found to be in a satisfactory condition, so far as their safe keeping is concerned.

We have laid on the table a list of the names of those Fellows who are in arrear for sums due at the last Annual General Meeting, with the amount due against each Fellow's name.

Robt. J. Lecky.
Richard Inwards.

Stock in hand of volumes of the *Memoirs* :—

Vol.	At Society's Rooms	At Williams & Norgate's	Vol.	At Society's Rooms	At Williams & Norgate's
I. Part 1	6	...	XXIX.	413	...
I. Part 2	41	...	XXX.	163	...
II. Part 1	52	...	XXXI.	145	...
II. Part 2	19	...	XXXII.	159	...
III. Part 1	66	1	XXXIII.	166	1
III. Part 2	85	1	XXXIV.	166	6
IV. Part 1	80	3	XXXV.	110	6
IV. Part 2	92	3	XXXVI.	201	10
V.	107	4	XXXVII. Part 1	342	4
VI.	126	3	XXXVII. Part 2	285	4
VII.	150	3	XXXVIII.	279	1
VIII.	128	3	XXXIX. Part 1	251	4
IX.	135	3	XXXIX. Part 2	256	4
X.	148	...	XL.	279	1
XI.	155	...	XLI.	429	1
XII.	162	...	XLII.	244	2
XIII.	165	1	XLIII.	254	1
XIV.	373	3	XLIV.	236	1
XV.	141	...	XLV.	275	2
XVI.	168	1	XLVI.	279	5
XVII.	149	2	XLVII. Part 1	3	...
XVIII.	149	...	XLVII. Part 2	21	...
XIX.	155	...	XLVII. Part 3	2	...
XX.	156	...	XLVII. Part 4	13	...
XXI. Part 1	314	...	XLVII. Part 5	13	...
XXI. Part 2	99	...	XLVII. Part 6	13	...
XXI. 1 & 2 (together)	63	1	XLVII.	300	6
XXII.	157	...	XLVIII. Part 1	460	9
XXIII.	152	...	Index to *Memoirs*	646	1
XXIV.	159	1			
XXV.	170	...			
XXVI.	174	2			
XXVII.	426	...			
XXVIII.	386	...			

Stock in hand of volumes of the *Monthly Notices* :—

Vol.	At Society's Rooms	At Williams & Norgate's	Vol.	At Society's Rooms	At Williams & Norgate's
I.	70	...	XXIV.	23	...
II.	72	...	XXV.	7	...
III.	...	...	XXVI.	9	...
IV.	...	...	XXVII.	3	...
V.	...	...	XXVIII.	71	1
VI.	38	1	XXIX.	52	...
VII.	2	...	XXX.	66	2
VIII.	139	2	XXXI.	97	...
IX.	22	3	XXXII.	117	5
X.	175	1	XXXIII.	102	2
XI.	185	1	XXXIV.	82	2
XII.	11	2	XXXV.	64	1
XIII.	150	3	XXXVI.	32	1
XIV.	109	3	XXXVII.	39	3
XV.	124	2	XXXVIII.	102	1
XVI.	107	2	XXXIX.	100	1
XVII.	136	1	XL.	114	3
XVIII.	166	...	XLI.	115	5
XIX.	57	...	XLII.	122	4
XX.	34	...	XLIII.	128	5
XXI.	17	...	XLIV.	131	10
XXII.	32	...	Index to *Monthly Notices*	582	2
XXIII.	28	...			

In addition to the above volumes of the *Monthly Notices*, the Society has a considerable stock of separate numbers of nearly all the volumes. With the exception, however, of Vols. XXXVI. to XLIV. no complete volumes can be formed from the separate numbers in stock.

Instruments belonging to the Society.

No. 1. The *Harrison* clock.
„ 2. The *Owen* portable circles, by Jones.
„ 3. The *Beaufoy* circle.
„ 4. The *Beaufoy* transit instrument.
„ 5. The *Herschel* 7-foot telescope.
„ 6. The *Greig* universal instrument, by Reichenbach and Ertel. The transit telescope, by Utzschneider and Fraunhofer, of Munich.

No. 7. The *Smeaton* equatoreal.
„ 8. The *Cavendish* apparatus.
„ 9. The 7-foot Gregorian telescope (late Mr. Shearman's).
„ 10. The variation transit instrument (late Mr. Shearman's).
„ 11. The universal quadrat, by Abraham Sharp.
„ 12. The *Fuller* theodolite.
„ 13. The standard scale, by Troughton and Simms.
„ 14. The *Beaufoy* clock, No. 1.
„ 15. The *Beaufoy* clock, No. 2.
„ 16. The *Wollaston* telescope.
„ 17. The *Lee* circle.
„ 18. The *Sharpe* reflecting circle.
„ 19. The *Brisbane* circle.
„ 20. The *Baker* universal equatoreal.
„ 21. The *Reade* transit.
„ 22. The *Matthew* equatoreal, by Cooke.
„ 23. The *Matthew* transit instrument.
„ 24. The *South* transit instrument.
„ 25. A sextant, by Bird (formerly belonging to Captain Cook).
„ 26. A globe showing the precession of the equinoxes.
The *Sheepshanks* collection :—
„ 27. (1) 30-inch transit instrument, by Simms, with level and two iron stands.
„ 28. (2) 6-inch transit theodolite, with circles divided on silver; reading microscopes, both for altitude and azimuth; cross and siding levels; magnetic needle; plumbline; portable clamping foot and tripod stand.
„ 29. (3) $4\frac{6}{10}$-inch achromatic telescope, about 5 feet 6 inches focal length; finder; rack motion; double-image micrometer; two other micrometers; object-glass micrometer; one terrestrial and ten astronomical eyepieces, applied by means of two adapters; equatoreal stand, and clock movement.
„ 30. (4) $3\frac{1}{4}$-inch achromatic telescope, with equatoreal stand; double-image micrometer; one terrestrial and three astronomical eyepieces.
„ 31. (5) $2\frac{3}{4}$-inch achromatic telescope, with stand; one terrestrial and three astronomical eyepieces.
„ 33. (7) 2-foot navy telescope.
„ 34. (8) Transit instrument of 45 inches focal length; with iron stand, and also Ys for fixing to stone piers; two axis levels.
„ 35. (9) Repeating theodolite, by Ertel, with folding tripod stand.
„ 36. (10) 8-inch pillar sextant, by Troughton, divided on platinum, with counterpoise stand and artificial horizon.

No. 37. (11) Portable zenith telescope and stand, $2\frac{3}{4}$-inch aperture and 26 inches focal length; 10-inch horizontal circle and 8-inch vertical circle, read to 10″ by two verniers to each circle.

„ 38. (12) 18-inch Borda repeating circle, by Troughton, $2\frac{1}{8}$-inch aperture and 24 inches focal length; the circles divided on silver, the horizontal circle being read by four verniers, and the vertical circle by three verniers, each to 10″.

„ 39. (13) 8-inch vertical repeating circle, with diagonal telescope, by Troughton and Simms; circle divided on silver, reading to 10″; a 5-inch circle at eye-end reading to single minutes; horizontal circle 9 inches diameter in brass, reading to single minutes.

„ 40. (14) A set of surveying instruments, consisting of a 12-inch theodolite for horizontal angles only, reading to 10″; two sets of adjusting plates; tripod stand with enclosed telescope; heavy stand for theodolite; Y piece of level; two large and three small ground-glass bubbles divided; level collimator, object-glass $1\frac{5}{8}$-inch diameter and 16 inches focal length; micrometer eyepiece, comb, and wires; mercury bottle and trough.

„ 41. (15) Level collimator with object-glass $1\frac{7}{8}$-inch diameter and 16 inches focal length; stand, rider-level, and fittings.

„ 42. (16) 10-inch reflecting circle, by Troughton, reading by three verniers to 20″; counterpoise stand; artificial horizon with mercury; two tripod stands.

„ 43. (17) Hassler's reflecting circle, by Troughton, with counterpoise stand.

„ 44. (18) 6-inch reflecting and repeating circle, by Troughton and Simms, contained in three boxes, two of which form stands. Circle divided on silver, reading to single minutes; two inside arcs divided to single degrees, 150 degrees on each side; artificial horizon and mercury.

„ 45. (19) 5-inch reflecting and repeating circle, by Lenoir, of Paris.

„ 46. (20) Reflecting circle by Jecker, of Paris, 11 inches in diameter, with one vernier reading to 15″.

„ 47. (21) Box sextant; reflecting plane and level.

„ 48. (22) Prismatic compass, by Troughton and Simms.

„ 49. (23) Mountain barometer.

„ 50. (24) Prismatic compass, by Thomas Jones, mounted with a cylindrical lens.

„ 51. (25) Ordinary $4\frac{1}{2}$-inch compass with needle.

„ 52. (26) Dipping needle, by Robinson.

„ 53. (27) Compass needle, mounted for variation.

No. 54. (28) Magnetic intensity needle, by Meyerstein, of Göttingen; a strongly fitted brass box with heavy magnet; filar suspension.

„ 55. (29) Box of magnetic apparatus.

„ 56. (30) Hassler's reflecting circle, by Troughton; a 10½-inch reflecting and repeating circle, with stand and counterpoise, divided on platinum with two movable and two fixed indices; four verniers reading to 10″.

„ 57. (31) Box sextant and glass plane artificial horizon, by Troughton and Simms.

„ 58. (32) Plane 2⅜-inch speculum, artificial horizon, and stand.

„ 59. (33) 2½-inch circular level horizon, by Dollond.

„ 60. (34) Artificial horizon, roof, and trough; the trough 8¼ by 4½ inches: tripod stand.

„ 61. (35) Set of drawing instruments, consisting of 6-inch circular protractor and common protractor, T-square: one beam compass.

„ 62. (36) A pentagraph.

„ 63. (37) A noddy.

„ 64. (38) A small Galilean telescope with object-glass of rock crystal.

„ 65. (39) Five levels.

„ 66. (40) 18-inch celestial globe.

„ 67. (41) Varley stand for telescope.

„ 69. (43) Telescope, with the object-glass of rock crystal.

„ 70. Portable equatoreal stand.

„ 71. Portable altazimuth tripod.

„ 72. Four polarimeters.

„ 74. Registering spectroscope, with one large prism.

„ 76. Two five-prism direct-vision spectroscopes.

„ 78. 9¼-inch silvered-glass reflector and stand, by Browning.

„ 79. Spectroscope.

„ 80. A small box, containing three square-headed Nicol's prisms; two Babinet's compensators; two double-image prisms; three Savarts; one positive eyepiece, with Nicol's prism; one dark wedge.

„ 81. A back-staff, or Davis' quadrant.

„ 82. A nocturnal or star dial.

„ 83. An early non-achromatic telescope, of about 3 feet focal length, in oak tube, by Samuel Scatliffe, London.

„ 84. A Hollis observing chair.

„ 85. Double image micrometer, by Troughton and Simms.

„ 86. 4½-inch Gregorian reflecting telescope, by Short, with altazimuth stand and 6-inch altitude and azimuth circles and two eyepieces.

No. 87. 3¼-inch Gregorian reflecting telescope with wooden tripod stand.

„ 88. Pendulum with 5-foot brass suspension rod, working on knife edges, by Thomas Jones.

„ 89. A Rhabdological Abacus. A contrivance invented by Mr. H. Goodwyn, consisting of a box filled with compartments, in which are square rods covered with numbers, which can be arranged so as to facilitate the labour of multiplying high numbers.

„ 90. An Arabic celestial globe of bronze, 5¾ inches in diameter.

„ 91. Astronomical time watchcase, by Professor Chevallier.

„ 92. 2-foot protractor, with two moveable arms, and vernier.

„ 93. Beam compass, in box.

„ 94. 2-foot navigation scale.

„ 95. Stand for testing measures of length.

„ 96. Artificial planet and star, for testing the measurement of a fixed distance at different position-angles.

„ 97. 12-cell Leclanché battery.

„ 98. 2 feet 6 inch navy telescope with object-glass 2½ inches, by Cooke, with portable wooden tripod stand.

„ 99. 12-inch transit instrument, by Fayrer & Son, with level and portable stand.

„ 100. 9-inch transit instrument, with level and iron stand.

„ 101. Small equatoreal sight instrument, by G. Adams, London.

„ 102. Sun-dial, by Troughton.

„ 103. Sun-dial, by Casella.

„ 104. Sun-dial.

„ 105. Box sextant, by Troughton and Simms.

„ 106. Prismatic compass, by Schmalcalder, London.

„ 107. Compass, by C. Earle, Melbourne.

„ 108. Prismatic compass, by Negretti and Zambra.

„ 109. Dipleidoscope, by E. Dent.

„ 110. Abney level, by Elliott.

„ 111. Pocket spectroscope, by Browning.

„ 112. Small brass astrolabe.

„ 113. Double sextant, by Jones.

„ 114. Two models, illustrating the effects of circular motions.

„ 115. A cometarium.

„ 116. A pair of 18-inch globes.

„ 117, „ 118. Two old sun-dials.

No. 119. Specimens of rulings on speculum metal, by Prof. W. A. Rogers, presented by H. J. Chaney, Esq.
„ 120. A 6-prism spectroscope, by Browning, presented by J. D. Perrins, Esq.
„ 121. Improved maximum and minimum thermometer, presented by E. J. Spitta, Esq.

The following instruments are lent, during the pleasure of the Council, to the undermentioned persons:—

No. 4. The *Beaufoy* transit instrument, to the Observatory, Kingston, Canada.
„ 22. The *Matthew* equatoreal, to Mr. Brett.
„ 23. The *Matthew* transit, to Captain W. Noble.
„ 74. Registering spectroscope, with prism, to Mr. R. J. Lecky.
„ 99. 12-inch transit, to Rev. A. Freeman.

From the *Sheepshanks* collection:—

No. 27. (1) 30-inch transit instrument and stand, to Mr. G. M. Whipple.
„ 29. (3) Clock and equatoreal mounting, to Mr. R. Bryant.
„ 29. (3) Three micrometers, to Mr. E. Ristori.
„ 30. (4) $3\frac{1}{4}$-inch equatoreal and stand, to Mr. H. Sadler.
„ 31. (5) $2\frac{3}{4}$-inch telescope and stand, to Mr. E. Ristori.
„ 34. (8) Transit instrument, to Prof. C. Pritchard.
„ 36. (10) 8-inch pillar sextant, to Mr. R. Bryant.
„ 69. (43) Telescope, with rock-crystal object-glass, to Dr. W. Huggins.

No. 29. (3) Telescope, lent to the Transit of *Venus* Committee, and lost in the "City of Brussels," has not yet been replaced.

The Gold Medal.

The Council have awarded the Society's Gold Medal to Dr. Huggins for his researches on the motions of Stars in the line of sight, and on the photographic spectra of Stars and Comets. The President will lay before the Society the grounds upon which the award has been founded.

Publications of the Society.

Vol. XLVIII., Part 1, of the *Memoirs* has been published during the year. It contains the following paper:—

Heliometer Determinations of Stellar Parallax in the Southern Hemisphere. By David Gill and W. L. Elkin.

Vol. XLVIII., Part 2, is in the press, and will shortly be published. It will contain the following papers :—

Fourth Catalogue of Micrometrical Measures of Double Stars, made at the Temple Observatory, Rugby. By G. M. Seabroke.

On the Relative Proper Motions of 40 Stars in the *Pleiades*, determined from Micrometric and Meridional Observations. By Prof. C. Pritchard.

Observations of *Mars* at the Opposition of 1884. By E. B. Knobel.

On the Corrections required by Hansen's "Tables de la Lune." By E. Neison.

Sur une inégalité lunaire à longue période. By M. C. Gogou.

Obituary.

The Council regret that they have to record the loss by death of the following Fellows and Associate during the past year:—

Fellows:—Richard Abbatt.
Thomas Barneby.
H. G. Bohn.
Rev. J. C. Ebden.
Rev. W. Falconer.
H. A. Fletcher.
William Frost.
H. R. Janisch.
H. C. Levander.
J. L. Shuter.
Rev. F. Silver.
Isaac Todhunter.
Thomas Turner.
F. D. Wackerbarth.
Thomas Watson.

Associate:—Marian Kowalski.

Richard Abbatt, whose death took place on September 15, 1884, was one of the oldest Fellows of the Royal Astronomical Society, having been elected in 1833, February 8. He was born at Jivecelton, in Lancashire, in the year 1800. His father, Edward Abbatt, dying in 1802, his mother removed with her little son to Whitehaven, and from thence to Torpenhow to reside near her parents. About the age of twelve he was placed at a large boarding school in Yorkshire, and some years afterwards apprenticed to a grocer in Carlisle. Here, in consequence of an accident, his health gave way, and, at the earnest entreaties of his mother, his master cancelled his indentures. On his recovery he was placed at Mr. Saul's school at Greenrow, under whose tuition he made considerable progress in mathematics, a science which continued to possess great charms for him through a long life. He was employed as mathematical master in a school in Hammersmith, and this he resigned to accept the same post in a school about to be opened at Tottenham for the sons of the upper class of the Society of Friends, of which religious body his family had long been members. His first work, on the "Elements of Trigonometry," was published in 1834, his next was on the "Calculus of Variations" in 1836, when residing at Epping, where he had removed to commence a school in partnership with

Dr. Usmer, his friend and fellow assistant at the last two schools. He removed his school to Stoke Newington in 1839. Here he published "The Picts or Romano-British Wall," "The Principles and Practice of Linear Perspective;" "The Ascent of Scawfell Pike;" "The Two Estates, or Both Worlds Mathematically Considered;" "Physical Astronomy;" "Taught from Above," and others. His latest work was a pamphlet on Life Assurance, published in 1883. He also published two Orthographic Projections of the World representing the Earth floating in space. In the year 1870 he was chosen one of the party sent out to observe the eclipse of the Sun at Gibraltar; the account of this expedition was published in the *Carlisle Journal* and other papers. On retiring from school business, he was presented with a gold chronometer, a beautifully illuminated album containing portraits of his early friends and pupils, and 1,000 guineas, as a mark of their respect and esteem. The last years of his life were spent at a delightful spot in Burgess Hill, built for him by one of his old pupils. His bodily powers had been gradually failing for two or three years, yet his health and strength were far beyond what is generally expected in a man of his age. He died, after a short illness, at the age of eighty-four, and his remains were interred in Park Street, Stoke Newington, the resting-place of a large number of his early friends. In life he was a most amiable and unselfish man, endeared to a large circle of friends by the refinement of his mind, his patient spirit, and his strict conscientious character. He was a most entertaining companion, possessing a wonderful memory of almost every book he had read, and the kind sympathy that accompanied all his actions won the respect and affection of all who knew him. Mr. Abbatt's favourite studies were mathematics and astronomy, and the pleasant and successful manner he possessed of imparting his own love for these subjects is remembered by many of his early pupils who still survive him.

Henry George Bohn was born in London on January 4, 1796. He claimed to be descended from a family of the name of Bohun, who being among the Protestant refugees who passed to the Continent in the reign of Mary, became possessed of estates at Weinheim, on the Rhine. His father, John Henry Martin Bohn, who had served his apprenticeship in Germany, settled in London, and carried on the business of a bookbinder and second-hand bookseller, in which he was assisted by his son.

Mr. Bohn had an early ambition to be a publisher; but not until 1846 did he commence the issue of the reprints and translations which constitute the Standard and other Libraries, and for which his name became so celebrated. It is to the enterprise of Mr. Bohn that we owe the introduction of so much good literature at a low price. His various "Libraries," The Standard, The Scientific, The Illustrated, The Classical, The Antiquarian,

&c., amounted to more than six hundred volumes, and the success which has attended their sale is an indication of the excellence of the publications.

He was a man of great energy, immense power of work, and great shrewdness. Constable had shown that books of a light and popular character would, if sold at a low price, meet with an extensive sale. Mr. Bohn proved that works of a solid cast, such as had been hitherto attainable only at high prices, would excite a remunerative demand if brought out at low rates. He certainly was one of the chief pioneers of cheap literature.

Mr. Bohn, who, for many years, had lived in York Street, Covent Garden, eventually resided entirely at Twickenham, where he devoted himself to gardening, and buying china and pictures.

Mr. Bohn married, in 1831, a daughter of the late Mr. Simpkin, who, with her two sons and daughter, survive him.

He was elected a Fellow of the Society on January 11, 1861.

John Henry Dallmeyer. In the annual report last year the Council were only able briefly to announce their regret at the news of the decease of this gentleman, who was for many years a member of this Society. They desire to add some further tribute to one who rendered, by his optical skill, such important service to Astronomy.

Mr. Dallmeyer commenced his career in this country in the employ of the late Mr. Andrew Ross (afterwards his father-in-law), under whose encouragement and tuition he cultivated and manifested his capabilities in both the mechanical and optical departments of his calling. His name was first brought to public notice in Sir John Herschel's article on "The Telescope" (in the *Encyclopædia Britannica*, 8th edition), in which a list of the most important refractors then known is given, and, as to several, it is noted that Mr. Dallmeyer laid claim "to the personal execution and the computation of their curvatures."

At the death of Mr. A. Ross in 1859, Mr. Dallmeyer started business for himself, confining his attention at first almost entirely to the astronomical telescope; he constructed several very fine object glasses, some of which were employed in the recent eclipse and transit of *Venus* expeditions. He did not construct many large instruments, the largest being of 8-in. aperture; but his process of polishing (a long and difficult one, conducted under water) enabled him to produce a "black" polish on the surfaces rarely met with.

At the International Exhibition of 1862 Mr. Dallmeyer showed that he had turned his attention to the construction and improvement of the photographic lens, and it is in "photographic optics" that he chiefly proved himself a thorough master of his subject, and rendered such important services to photography in all its branches.

His improvements in lenses for all kinds of work, and for

which he took out many patents, followed rapidly one after another. He was rewarded by the first honours as an exhibitor, and received from foreign Governments decorations in recognition of his services. The topographical departments of our own and other Governments left the optical work entirely in Mr. Dallmeyer's hands.

It is chiefly upon photographic optics that he contributed papers to periodicals, and his practical pamphlet "On the Choice and Use of Photographic Lenses" is well known. In the furtherance of celestial photography Mr. Dallmeyer aided largely in the construction of the photo-heliograph. The first that he supplied was to the Russian Government in 1863 for the Wilna Observatory, for taking 4-in. pictures of the Sun. This proved a great success, and the Harvard College Observatory was supplied with one the following year.

In 1873 five photo-heliographs of 4-in. aperture and 5-ft. focal length with secondary magnifiers, giving 4-in. Sun pictures, were supplied to the Government. These were all mounted on universal equatorial stands, and went to various destinations for the transit of *Venus* expeditions in 1874. They have been since employed in solar photography, and some have lately been fitted with new magnifiers giving 8-in. pictures.

Mr. Dallmeyer's work in the construction of microscope object-glasses is well known and appreciated.

His last effort was in the "Optical Lantern," which he endeavoured to make a scientific and perfect instrument at the request of his old friend the Rev. F. Hardwich, who was also the first to test and to report on the first photographic lens that Mr. Dallmeyer constructed. The importance of the Optical Lantern has asserted itself, and Mr. Dallmeyer's work did what was necessary in giving the true rendering in colour and line.

For some three years previous to his decease he suffered from ill-health, due to overwork, and was obliged to make several voyages and journeys for restoration. During the last voyage which he undertook, he expired on December 30, 1883, in his fifty-second year, while between Tasmania and New Zealand. His affectionate and modest disposition made him endeared to all that knew him, and his indomitable energy prevented him from sooner relaxing his hand from his work, which he truly loved, or we might still have had him among us.

He was elected a Fellow of this Society on June 14, 1861.

James Collett Ebden was born at Loddon, Norfolk, on the 14th of August, 1794, and died at the vicarage, Great Stukeley, Hunts, on February 15, 1884, in the 90th year of his age, being at that date the Senior Fellow of the Society. He was the son of Mr. John Ebden of Haughley, Suffolk, by his second wife Elizabeth, daughter of Anthony Collett, Esq., of Eyke, and granddaughter of Robert May, Esq., of Sutton, who was High Sheriff of Suffolk in 1758. The Suffolk family of Collett had

been settled in the county from the fifteenth century, and was a branch of the Colletts or Colets of Wendover, of whom was Sir Henry Colet, twice Lord Mayor of London, and father of the celebrated Dean of St. Paul's. Mr. Ebden received his school education at Stowmarket, whence he proceeded in 1813 to Caius College, Cambridge. He graduated in 1816 as sixth wrangler, having amongst his competitors Dr. Whewell, the late Master of Trinity College, second wrangler, Professor Cape, fifth wrangler, and Richard Sheepshanks, sometime Vice-President of the Society, tenth wrangler. He was elected in 1816–17 a Fellow of Caius College, and in 1817–18 Fellow and Tutor of Trinity Hall, which post he held for ten years, numbering amongst his pupils Lord Chief Justice Cockburn, the late Lord Lytton, and other distinguished members of the college and university. In 1821–22 he was appointed Vice-Master of Trinity Hall. He married in 1828 Eliza, daughter of Sydenham Feast Wylde, Esq., of the 7th Hussars, and granddaughter of Penyston Portlock Powney, Esq., M.P. for Windsor. Mr. Ebden was one of the original members of the Athenæum Club and of the British Association for the Advancement of Science, the annual meetings of which society he attended without intermission till he was past eighty years of age. He was distinguished as a classical and English scholar, and was well versed in the languages and literatures of several foreign countries. He was associated with Messrs. Riddle and Arnold in their lexicographical undertakings, and he is believed to have been engaged in earlier life upon other literary and scientific work, although he has not left any record by which it can be ascertained and verified. He was nevertheless possessed of accurate and very varied scientific knowledge, and took a warm interest in the objects and proceedings of the British Association until he was confined to his home by increasing age and infirmity.

Mr. Ebden was elected a Fellow of the Society on June 9, 1820.

William Frost was born on August 19, 1805, at Thorpe-le-Soken, Essex. He married a daughter of Mr. W. J. Frodsham, and from 1832 to 1865 resided at Hackney, subsequently removing to Tulse Hill. He was the author of several works; among others an "Arithmetic," and "Arithmetical Tables," "Uranian Guide," "View of the Earth and Heavens," and "A Celestial Atlas."

He was a man of considerable energy and perseverance, making friends wherever he went, and was highly respected in every relation of life.

He was for many years a member of the British Association. He died on March 10, 1884, at Tulse Hill, where a memorial has been since erected in Trinity Church, "by those who, having known and valued him, desire to perpetuate his memory in the Church he loved and served so well." He was elected a Fellow of the Society on April 13, 1838.

Henry Charles Levander, M.A., a native of Norwich, received his education at the Exeter Grammar School and at Pembroke College, Oxford. He soon distinguished himself by his extensive reading in ancient and modern languages, both eastern and western, and in mathematics, in which he graduated with honours. His power to acquire knowledge was very great, and, gifted with great determination and a very retentive memory, there was hardly any branch of science in which he was not proficient. He was some years ago appointed one of the masters of University College School. He took a special interest in astronomy, but although possessing an Equatorial, his numerous avocations did not allow him much time for making observations. He was elected a Fellow of this Society on April 12, 1872; he was also a Fellow or member of several other learned societies.

James L. Shuter was born June 21, 1819. From his early youth to his last day he took the greatest interest in all that appertained to science, being specially attached to mechanics; and he owed his position and success in life entirely to his own unaided efforts and to his untiring thirst after knowledge.

He constructed two telescopes, the larger one being of about 4 inches aperture; and he originated a considerable improvement in the geometric chuck, which is described in the *English Mechanic*, for May 30, 1884. His wife died February 16, 1883. Two daughters survive him. His only son, Mr. James Shuter, F.R.C.S., Assistant-Surgeon to St. Bartholomew's and the Royal Free Hospitals, died November 1, 1883.

Mr. Shuter was a Fellow of the Chemical Society and the Society of Arts, and a member of the Amateur Mechanical Society. He was formerly a Fellow of the Geological and Meteorological Societies.

He was elected a Fellow of this Society February 13, 1863.

Frederick Silver was born at St. John's Wood, London, in 1821. He received a private education in the early part of his life, afterwards proceeding to Worcester College, Oxford, where he graduated about the year 1846.

Soon after leaving Oxford he took holy orders, and eventually held the living of Norton, Market Drayton, where he was rector for more than thirty years.

Though laying claim to no high intellectual power, he was possessed of a kind and benevolent spirit, which he exercised for the benefit of those within his circle, and especially the humbler classes. At frequent intervals he gathered in his rectory grounds large numbers of the working classes from the neighbourhood for the purpose of lectures upon botanical, geological, and kindred subjects, and also to inspect the objects in his museum, the collection of which had occupied his attention for many

years. He thus endeavoured to elevate the masses and foster an interest in things superior to their everyday surroundings. He died at Norton, Market Drayton, on August 28, 1884.

His only child, a son, graduated at Christ Church, Oxford, but died shortly after taking holy orders.

Mr. Silver was for many years a Fellow of the Linnæan, Royal Geographical, Geological, and Meteorological Societies.

He was elected a Fellow of this Society on May 11, 1855.

Isaac Todhunter was born in 1820, and was the second son of a Congregationalist minister at Rye. Passing over his boyhood we find him an assistant-master in a school at Peckham, and at the same time attending the evening classes at University College, and among others the lectures of De Morgan. Here he seems to have come under the fascination which so many of the pupils of that great teacher experienced. His admiration for that mathematician was unbounded. He obtained great distinction in the University of London, carrying off the honours at the degrees of B.A. and M.A. He afterwards entered the University of Cambridge, and became Senior Wrangler and first Smith's Prizeman in 1848.

In the same year in which he took his degree he gained the Burney Prize. According to the regulations this prize is to be awarded for an English essay, to a graduate of the University who is not of more than three years' standing from admission to his first degree. His essay was printed in 1849 under the title "The doctrine of a Divine Providence is inseparable from the belief in the existence of an absolutely perfect Creator."

Soon after taking his degree he established himself at St John's College as a mathematical tutor and lecturer, but afterwards he gave up all share in the tuition of his college and devoted himself more and more to the work of writing books.

The great work of Dr. Todhunter's life lies in the part he has taken in the education of this generation. A detailed account of the numerous educational books he has written would be too long for so slight a sketch of his life as the present. His books conduct the student from the beginning through a long course of mathematical learning. A simple list of these is a history of the labours of his life; as the dates run on we see his time filled up with correcting one edition after another.

In constructing his books, he seems to have discovered that, for the teaching of boys, novelties would be out of place. What was wanted in any subject was a short and accurate account of the things then known. The object was to put the reader as quickly as possible in possession of all the knowledge which was most likely to be useful to him afterwards. Accordingly he gives in his books a clear statement of the well-known principles of each subject, arranged in a logical order. Each step in the argument is explained at length in clear English. Nothing is assumed but what a reader should know. Every page makes it

evident how thoroughly he was keeping in mind that he was writing for beginners.

Whatever his own ideas were, his books were certainly a great success. His "Euclid" and his "Elementary Algebra" have in twenty years run through fifteen or sixteen editions. They were appreciated by the schoolmasters, and by those who had to teach these subjects. With their recommendations, the sale has grown into something enormous. His more advanced text-books, being addressed to a more limited circle of readers, could not be expected to run through so many editions; yet we find his "Differential Calculus" reaching its ninth and his "Integral Calculus" a seventh edition.

His reputation in future time will undoubtedly rest on his histories, for the fashion of elementary books will pass away, and a new generation will like a new arrangement of old things. The most important of these are (1) "A history of the progress of the Calculus of Variations during the nineteenth century:" 1861; (2) "A history of the Mathematical Theory of Probability from the time of Pascal to that of Laplace:" 1865; (3) "A history of the Mathematical Theories of Attraction and the Figure of the Earth from the time of Newton to that of Laplace:" 1873. The first of these is a continuation of Woodhouse's history of the Calculus of Variations from its origin until the close of the eighteenth century; and it has been stated that it was his admiration for this work that led him to write this history.

These books appear to the writer of this notice to be of great importance. It is a great boon to the student to have a short and clear account of what has been already done, and what remains to be accomplished in any subject. Though the third of these histories extends over two volumes of nearly five hundred pages each, yet these are not too much for so great a subject.

It is unnecessary to give a particular account of these histories, as they have now been some time before the public. But we would call the attention of those who have not yet read them to their extreme interest. As we read one of them it seems as if a new light were thrown on the subject. The difficulties of each investigator are put before us; we see how the subject advances, each discoverer adding a little, until step by step we arrive at our present state of knowledge. We see here sketched out before us the gradual growth of those modern methods which we now find so ready to our hands. Thus, in one place, Dr. Todhunter points out the first appearance of those confocal shells which play so important a part in modern works of attraction. These appear in a memoir of Maclaurin's, who introduces them in a remarkable manner without appearing to realise their importance. In another place, we find a sketch in eight pages of a memoir of Legendre's which Dr. Todhunter considers to be the foundation of all that Laplace added in the theories of attraction and the figure of the Earth to the works

of Maclaurin and Clairaut. As we read the sketch, we see the first beginning of Laplace's coefficients and a recognition of the importance of the potential. This was the commencement of a new era in mathematical physics. In a third place, the history shows us how D'Alembert, trying to find the attraction of an ellipsoid, makes it depend on a single definite integral. This result, Dr. Todhunter reminds us, is the point at which modern investigations have finally arrived. But D'Alembert, after effecting this, strangely rejects his result as inadmissible. "In his process," says Dr. Todhunter, "there is nothing wrong in principle, but he has omitted a bracket which renders his result slightly inaccurate. He gives some invalid argument against his method. Thus D'Alembert deliberately rejects one of the most important formulæ of the subject, which in fact quite supersedes a large part of his memoir. This is perhaps the strangest of all his strange mistakes." A little further on in the history, we read how Laplace values and appropriates the treasure which D'Alembert deliberately threw away.

Dr. Todhunter has contributed a few papers to the societies to which he belonged. These are chiefly historical, and seem to have risen out of the histories on which he spent so much of his time. Some are occupied with discussions on the errors into which former writers have fallen, while others contain extensions of theorems already established. To the Royal Astronomical Society he contributed two short papers, which have both appeared in the *Monthly Notices*. In the first of these he mentions what seems to be a curious contradiction between the reasoning given in props. 36 and 37 of the third book of Newton's "Principia" and the statement made in prop. 38 of the same book. In the first two Newton discusses the forces of the Sun and Moon to move the sea, and in the last he applies the same general reasoning to find the figure of the Moon as disturbed by the attraction of the Earth. Yet while the first are quite correct, the last is wrong. The interest of the paper lies in the fact that, though this mistake was pointed out, with some emphasis, as long ago as a little past the middle of the last century, yet it does not seem to have been generally noticed by commentators on the "Principia." The second paper contributed to the Royal Astronomical Society is devoted to geodesy. An arc of the meridian measured in 1752 by La Caille, an astronomer whose accuracy has a great reputation, was found to be decidedly longer than might have been expected from measurements made in the northern hemisphere. The arc has in recent times been again measured by Sir T. Maclear, whose result is more in harmony with the northern arcs. But though the excellence of Maclear's work is beyond question, yet various difficulties and contradictions remain. These are shortly summed up by Dr. Todhunter with the hope of obtaining some explanations from those engaged in the measurements. In connection with this subject we may here allude to a longer paper contributed by Dr. Todhunter to the

twelfth volume of the *Cambridge Transactions* (1871). This is practically a history of the measurement of the famous Lapland arc first by the French and afterwards by the Swedish astronomers. He says that though the accounts of these measurements are easily accessible and written by distinguished astronomers, they yet contain numerous and serious errors. The arc then measured is a small one (being less than one degree), and therefore now unimportant when compared with the large arcs which have been since measured. The interest is, therefore, chiefly historical. It was maintained by Cassini in opposition to Newton, that the polar diameter of the earth was longer than the equatorial diameter. The operations carried on in Lapland by Maupertuis showed that the length of a degree of the meridian at the arctic circle was 57,437 toises. This was about 1,000 toises larger than it should have been according to the Cassinian theory. The result astonished the French observers. It is said that they kept this very secret, in order to reflect at leisure on what had been so little expected, and to have the pleasure of bringing the first intelligence of it to Paris.

Dr. Todhunter has also written four papers connected with the theory of the Figure of the Earth. Three of these are published in the *Proceedings* of the Royal Society. The first of these (vol. xix.) is on Jacobi's theorem on the ellipsoid of relative equilibrium and on Ivory's discussion of the theorem. In the second (vol. xx.) he gives an extension of the theorem of Poisson on the attraction of spheroids. In the third (vol. xxi.) he corrects a mistake of Dahlander. In a fourth paper, in the twelfth volume of the *Cambridge Transactions* he begins with the fundamental equation to find Yn in the Figure of the Earth; he then examines the various proofs that the only admissible value of Yn is zero given by Legendre, Laplace, O'Brien, &c., and points out the objections to each. He then concludes with a proof of his own.

We have occupied so much space with remarks on those papers of Dr. Todhunter which are more nearly connected with astronomy, that we have no room for more than an allusion to his other writings. There is a paper in the eleventh volume of the *Cambridge Transactions* on the method of Least Squares, which was evidently suggested by his history of the Mathematical Theory of Probability. In two papers in the *Proceedings* of the Royal Society for 1875 and 1878 he discusses the value of the integral of a product, first, of two, and next, of three of Legendre's functions.

In 1869, the subject prescribed for the Adams' Prize was "A determination of the circumstances under which Discontinuity of any kind presents itself in the solution of a problem of Maximum or Minimum in the Calculus of Variations." The proposal of this subject seems to have arisen from a controversy which had been carried on in the *Philosophical Magazine* a few years previously. In this controversy Dr. Todhunter had taken part, and

when the subject was proposed for the essay he was anxious that his own view should prevail. This view is given in the opening sentences of his essay:—"We shall find that, speaking generally, discontinuity is introduced by virtue of some restriction which we impose, either explicitly or implicitly, in the statement of the problems which we propose to solve." This thesis he supports by considering in turn the usual applications of the calculus, and pointing out where he considers the discontinuities which occur to have been introduced into the conditions of the problem. This he successfully proves in many instances. In some cases, the want of a distinct test of what discontinuity is, somewhat obscures the argument. His essay was rewarded with the prize. It is published under the title "Researches in the Calculus of Variations."

In the midst of so busy a life, Dr. Todhunter could yet find time to write for others. The second edition of Boole's "Differential Equations" was published under his care; and, what is more, he undertook the labour of arranging and editing the supplementary volume. This task was undertaken from friendship to the late Professor Boole. The difficulty of preparing unfinished papers for the press is obvious; and it is not surprising that, as he once mentioned to the writer, it should have cost him some months of hard work.

Dr. Todhunter has left a treatise on Elasticity, which was very nearly finished. The time and labour he spent over this work injured his eyesight, and probably led to his final illness. These MSS. had been sent to Professor Cayley to report on; and we learn from Professor Mayor's pamphlet that the investigation shows that they are of the same class as the history of the Theory of Attraction, and seem fairly complete.

Another result of the labours of his latter years is a treatise on Arithmetic. Such a work when perfected would have smoothed the way for the young beginner over many difficulties. It is greatly to be regretted that he did not undertake it sooner.

In the summer of 1880 Dr. Todhunter first began to suffer from his eyesight, and from that date he gradually and slowly became weaker. But it was not until September 1883, when he was at Hunstanton, that the worst symptoms came on. He then partially lost by paralysis the use of the right arm, and, though he afterwards recovered from this, he was left much weaker. In January of the next year he had another attack, and on March 1, 1884, he died at his own residence in Cambridge, surrounded by his dearest relatives. It was a fit ending to an honourable and respected life spent in the advancement of that science which he loved so well.

He was a member of many learned societies. He became a Fellow of the Royal Society in 1862, and served on the Council during the years 1871–1873. He was elected a member of the Mathematical Society of London in 1865, the first year of its

existence. He was elected a Fellow of this Society on January 11, 1850, and was a member of the Council during the two years from February 1868 to February 1870. Lastly, when the University of Cambridge established its new degree of Doctor of Science, restricted to those who have made original contributions to the advancement of science or learning, he was one of those whose application was granted within the first few months.

E. J. R.

Thomas Turner was born at Hull, December 13, 1804, and was the third son of Ralph Turner, a merchant of that place. He was educated at Bingley School, in Yorkshire, under the Rev. Dr. Hartley, and subsequently under the tutelage of the Rev. C. Bird, late Canon of Lincoln.

In 1823, he entered at Trinity College, Cambridge, of which he became a scholar and afterwards Fellow, having been second Wrangler and first Smith's Prizeman in 1827.

After taking his degree, he for a time took pupils, amongst whom was the late Mr. Milner Gibson. He then took up the study of law, and was called to the bar as a member of the Society of Lincoln's Inn. He practised as a barrister in London till 1846, when he retired from practice and devoted himself to philanthropic works. Upon the consecration of his valued friend, the Rev. Charles Perry, to the bishopric of Melbourne, he took much interest in the affairs of that diocese, and by his legal knowledge was able to give valuable assistance in obtaining the assent of the Queen to the act of the Victorian Parliament for the constitution of a Church of England Legislature in the colony.

About the same time also he was able to give much help to the people of Manchester, through his connection with Mr. Henry Charlewood, in obtaining the "Parish of Manchester Division Act," 1850, whereby the parochial duties of the dean and canons, and the disposal of the revenues were regulated, and provision was made for the division of the ancient parish of Manchester into separate rectories. Great research was necessary, and the effect of various charters had to be considered. To this difficult subject Mr. Turner devoted his time and talents, and to the assistance he gave the comprehensiveness and value of that Act was largely due.

About 1848 he was made a magistrate for the county of Middlesex, and was for several years chairman of the Parliamentary Committee, besides being an active member of several other committees. He was subsequently made a deputy-lieutenant of the same county.

In 1855, on the passing of Sir B. Hall's Local Government Act, he was elected as a member of the Metropolitan Board of Works, for Hampstead, and later on, after his removal to Southwark, he became a member of the Board, for St. Olave's.

In 1856, Mr. Turner undertook the office of treasurer to

Guy's Hospital, and principally resided there during the twenty years he held it. He did much for the advancement of that institution, and of the Medical School connected with it, and his work was highly appreciated there.

Previous to his resignation of the treasurership of Guy's Hospital in 1876, Mr. Turner's health had already begun to fail, and it continued to do so, very gradually, until on April 9, 1883, his energetic and useful life came to an end.

Mr. Turner was one of the earliest Fellows of the Royal Astronomical Society, and took much interest in that science. Though he made no important contribution to this or other branches of science, he had many friends among those engaged in them. Among the most distinguished of whom was Sir George Airy, late Astronomer Royal, who had been his college tutor.

Amongst other subjects, Mr. Turner devoted much time to the study of Hebrew, and published a Metrical Version of the Book of Psalms, from the original text.

In 1835 he married Mary Anne, daughter of the Rev. Charles Benjamin Charlewood, of Oak Hill, near Cheadle, in Staffordshire, the issue of the marriage being three sons and four daughters, four of whom are still living.

Mr. Turner was elected a Fellow of the Society on May 11, 1832.

Francis Diedrich Wackerbarth was born in London on January 30, 1813. He was descended from an old German family whose patrimonial estate was the baronial manor of Rogel in the ancient Duchy of Lauenburg. A descendant of this family, George Wackerbarth, came in the year 1752 to London, and there founded a sugar refinery, which afterwards descended to his son John Henry Wackerbarth, who died 1818. His son Francis Diedrich, one of a family of ten, was considered by those around him as most suitable for the clerical profession, and accordingly he received an education intended to qualify him for it. In the year 1831 he left the Rev. Dr. Laing's school in Clapham for Cambridge, well grounded in classics and mathematics. He took his degree as B.A. in 1835, and left Cambridge in 1837, having been appointed to the curacy of Peldon, in Essex. A few years later he became a minor canon of Lichfield Cathedral, but as early as 1841 he entirely abandoned the clerical profession and joined the Roman Catholic Church, receiving in his baptism the name of Athanasius.

During this short period of his life, viz., from 1837–41, he developed a remarkable literary activity, which was connected with the gradual approximation of his views to those of the Roman Catholic Church. Works written by him during this period are: "Music and the Anglo-Saxons; being some account of the Anglo-Saxon Orchestra, with remarks on the Church Music of the Nineteenth Century," London, 1837; "The Alleged Connexion between the Church of England and Luther-

anism," London, 1839; "The Revival of Monastic Institutions and their Bearing upon Society," Colchester, 1839; "Tuba Concordiæ, or a Letter to the future Prime Minister relative to the Pacification of Ireland and the Condition of the Church," Lichfield, 1841; "The Egyptian Bondage, or a Second Call to Union," London, 1842. It lies beyond the province of this biography to touch, if ever so briefly, on the contents of these works, but we may remark, in passing, that they are characteristic of a prominent feature in Mr. Wackerbarth's disposition, viz., always to express boldly his conviction, and to act without hesitation upon it—nay, even to suffer for the opinions he embraced. It is significant of Mr. Wackerbarth's activity that whilst he was curate of Peldon he appears to have rendered some important assistance in making the necessary calculations for the construction of a railway.

After his secession to the Romish Church he lived chiefly in private life, devoting himself to studies, among which languages took the most prominent place. He thus spent somewhat above ten years in England, for the greater part of which time he resided in Hammersmith. He was Professor of Anglo-Saxon at St. Mary's College, Oscott, and in the year 1849 published his "Beowulf," an epic poem translated into English verse, and printed in London the same year. A critique of this work is to be found in *The Weekly and Monthly Orthodox*, 1849. The same year he became a member of "Kong. Nordisk Oldskriftselskap i Köpenhavn."

In the year 1851 Mr. Wackerbarth undertook a journey to Copenhagen for the study of languages. He paid a visit to Upsala at the same time and found the state of things there so congenial to his tastes that he returned in April of the following year to remain there for life. In 1853 he became naturalised as a Swedish subject. On his first visit to Upsala he had made acquaintance with the director of the Astronomical Observatory, Professor G. Swanberg, and in this way was soon intimately connected with this institution. Astronomy always formed one of his favourite studies. He presented to the Observatory his refractor, a good instrument, though small, and he diligently shared in the astronomical work. Extremely unpretentious as regarded himself, he willingly accepted, in 1860, the office of *Amanuensis* to the Observatory, the only official post which could be offered to him, and which he managed during eighteen years with the greatest accuracy. Among the purely astronomical works which he published during this period are "Om Planeten Neptunus," printed in the Report of the University of Upsala for 1865, and a provisional theory of "Leda," Nov. acta R. Soc. Sc. Upsaladensis 1866. He is besides known in the astronomical world through his papers in the *Monthly Notices*. Other scientific works which he published during his sojourn in Sweden are "5-ställiga Logarithmer," with tables for numerical calculations, a book which is both well arranged and much used in

Sweden; "On the Great Pyramid of Gizeh," originally written for a Swedish periodical, but translated into English, and printed in London, 1871, in which he disputes the opinion that the dimensions of the above-mentioned pyramid contain intentional expressions for certain astronomical constants; "Hymn of St. Ephrem Syrus," London, 1852, a metrical translation from Syriac to English, and the little pamphlet "Om de gamla Egyptiska läroverken," Upsala, 1871, in which, on the strength of Mr. Chaba's book, "Voyage d'un Egyptien en Syrie, etc.," he makes some remarks respecting the University of Egypt in the time of Ramases the Great, are also monuments of his studies in Eastern literature. But much intelligent work has been executed by Mr. Wackerbarth which has not been published by himself. Wherever he could assist by his knowledge and his perseverance it was a real pleasure to him to do so. One might be sure that the work would be done quickly and well. Thus he has among other things contributed to the Syriac Lexicon, "Thesaurus Syriacus," published by the Rev. R. Payne-Smith, of Oxford, who honourably mentions his name in the second number of this great work.

The above gives but an imperfect idea of the extent of learning Mr. Wackerbarth possessed. He had the most thorough knowledge of the old classical authors. Next in order came the Semitic languages, Anglo-Saxon, and Icelandic. He was also a member of the Literary Society of Iceland; and besides the usual modern languages, he was well versed in Italian, Swedish, and Danish. He expressed himself with elegance and ease in verse, and in the *Dublin Review Advertiser* he published remarkably able translations of Tegnér, Runeberg, and Wallin. In history he had a vast knowledge, and quite uncommon insights in Church history. He was also a skilful sketcher of architectural objects, and well learned in the theory of musical composition, although few researches on these subjects were printed.

To complete the features of his life we must mention that he became a member of the Royal Society of Science in Upsala in 1858, and in 1866 he was there promoted to be honorary doctor by the Faculty of Philosophy. The same year he was presented with the Order of the "Northern Star." In 1859 he married the daughter of a Swedish rural dean, the Rev. C. O. Ekman, who alone survives him. In the year 1875 he was struck down by a fit, which considerably enfeebled his strong constitution, yet he continued to devote his remaining strength to scientific pursuits till a further attack of illness suddenly terminated his life on June 10, 1884.

Mr. Wackerbarth was, as one can readily see from the above sketch, a man gifted with an astonishing memory, an uncommon power for work, and an especial ability to grasp at once the most important parts of a subject. And without doubt it was a loss to science that the earlier stage of his life was devoted to other pursuits. In his views, as in his studies, he endeavoured

always to place himself as far as possible on the foundation of objective truth, and never spared any labour to attain this object.

For scientific metaphysics he entertained disgust, but still more for the want of clearness and consistency, and often even want of truth by which human work during the development of the great questions of the day is usually impaired. Perhaps this was partly the reason why he gladly sought subjects for his studies as well as foundations for his views far back in the history of the world, a tendency to which finds its expression in the motto (of Rabelais) with which he introduces his first work, "Music and the Anglo-Saxons," "*En quoy coignessez-vous la folie antique? En quoy coignessez-vous la sagesse moderne?*" A stranger to all kinds of dissimulation, he often displayed his views in a striking contrast to the opinions of the present day; yet supported as they were by his prodigious knowledge, and exposed with a particular clearness, they could not fail to compel attention, whilst, at the same time, he usually softened the contrast by an equally brisk and good-natured humour. He was very religious, yet without a trace of bigotry, and to the last moment his heart showed a youthful warmth and sympathy for others. In this way he drew his contemporaries into close communion with himself in spite of differences in rank and views. He was, therefore, also the favourite of the academical youth of Upsala, who elected him honorary member of two of their so-called "Nations," or college societies; at the same time he was highly valued by the elder academical world for his learning and character. He was buried in Upsala churchyard. The inscription on the wreath which the Academy of Sciences in Upsala then laid upon the grave of this noble stranger strikingly portrays his character: "*Varietate disciplinæ et copia omnia cepit, simplicitate animi et liberalitate omnes.*"

He was elected a Fellow of this Society on January 12, 1849.

F. L. E.

Ernst Friedrich Wilhelm Klinkerfues was born at Hofgeismar, in Hesse Cassel, on March 29, 1827; he was the eldest son of the surgeon of a Hessian regiment of Hussars. At an early age he was entrusted to the care of two aunts, who sent him first to the burgher school, and in his fourteenth year to the Gymnasium, at Cassel, where he found a home in the house of his uncle, the late Obergerichtsrath Dedolph. As a boy he is said to have been shy and studious, taking but little part in the ordinary amusements of his schoolfellows, although his affectionate disposition led him all the more keenly to enjoy the vacations spent with his brothers and sisters at their home, which was now at Spangenberg, where his father was professionally employed at the military hospital. Owing to the partiality displayed by Klinkerfues for the natural sciences, he left the Gymnasium for the Polytechnic School while yet in the

secunda, carrying with him the most flattering credentials from Dr. Weber, then director of the Gymnasium. On the death of his uncle Dedolph, Klinkerfues took lodgings in the house of an optician named Fiorino, in Cassel, and thus fell in with some old astronomical instruments, one of them being a reflecting telescope. He at once conceived a most ardent desire to learn the use of these instruments, a desire the more easily gratified in part, as his room in the "Colonnades" had a kind of balcony affording a free prospect of the heavens. At this time he began to study, with the greatest zeal, various astronomical books procured from the public library in Cassel, the Hessian "Landesbibliothek." Thanks to his training at the Gymnasium, he was able to read Lalande's "Astronomie," and later on Gauss' "Theoria Motus," in the original languages. After distinguishing himself at the Polytechnic School for industry and good behaviour, Klinkerfues passed his examination as surveyor (*Geometer*) in 1844, and eventually in 1846 was employed in the construction of the Main-Weser railway, but this did not prevent him from still drawing largely on the Cassel library for a supply of his favourite literature. Employed in the construction of the above-named railway, through the kindly interest of the director of the works (Obergerichtsrath Weiffenbach), Klinkerfues was stationed at Marburg, with special permission to attend the University lectures.

In this way Klinkerfues retained his post on the railway, and heard the lectures of the late Professor Gerling, besides taking part in the practical work at the Observatory; and, in common with a large class of zealous students, amongst whom were Professors Tyndall and Schönfeld, in the registration of the deflections of the magnetic needle. Klinkerfues' earliest observations of an eclipse of the Moon, some occultations, and also of *Ceres* and *Neptune*, are published in the 30th volume of the *Astronomische Nachrichten*.

Late in the spring of 1851, Klinkerfues resigned his post, and went to Göttingen with the warmest recommendations of Gerling, and with the somewhat reticent approval of Gauss, as we have just learnt through the publication, in No. 2573 of the journal just mentioned, of a most interesting letter from the great mathematician to Gerling, dated May 10, 1851. It is pleasant, however, to find that the same letter expresses the generous apprehension that undue caution on the writer's part may possibly have shaken Klinkerfues' intention of coming to Göttingen. In that University, however, Klinkerfues took up his residence in the summer session of 1851, and so far satisfied Gauss of his capabilities, that he was installed assistant at the Observatory at Michaelmas in the same year, having already taken part with Gauss and J. G. Westphal in the observation of the eclipse of the Sun on July 28. That autumn he computed two sets of elements of Eunomia, the first along with Westphal, who held the post of "Observator;" these were followed by elements of Comet IV., 1851. Shortly afterwards Klinkerfues

computed the difficult orbit of *Psyche*, preparing the way for the rediscovery of that planet in 1853. It is well known that Gauss was much gratified with the application of a special method given in the "Theoria Motus."

In June, 1853, Klinkerfues became more widely known through the discovery of Comet III. of that year, which afterwards became so bright as to be observed in the daytime at Olmütz and at Liverpool. This was the first of Klinkerfues' discoveries in this field, to which he afterwards added five other Comets—1854 III., 1854 IV., 1857 III., 1857 V., and 1863 II., besides independently finding Comets 1854 I., and 1855 II., the latter only one day after its discovery by Donati. To return to the year 1853—to all outward appearance nothing could be more promising than the career of the young astronomer, actively engaged in advanced theoretical studies, favourably known as a discoverer, and possessed of a phenomenal facility in the performance of elaborate calculations; and yet, even at this early stage, there is reason to fear that his private affairs were so seriously involved as materially to prejudice his further satisfactory advancement.

Gauss died on February 23, 1855, and the Göttingen Observatory was placed under the nominal direction of the well-known Professor W. Weber, with Klinkerfues as "Observator," in the place of Westphal, resigned. In this year Klinkerfues took his degree of Doctor of Philosophy, his inaugural dissertation being the essay, "Ueber eine neue Methode die Bahnen der Doppelsterne zu berechnen." In this year, also, he was made Assessor of the Royal Society of Sciences of Göttingen, but, unfortunately, was not destined to become a full member of that body. Amongst other labours about this time, an extensive series of zone-observations were commenced, in conjunction with Dr., afterwards Professor Schering, and various successive associates. The method of recording the declinations in these zones much resembled that introduced, with such signal results, by Gauss for following the variations of the magnetic needle. A mirror was fixed to the Transit-Circle, and in it were observed the reflected divisions of a fixed ivory scale, as seen through a large Transit instrument, mounted in the same meridian as the Transit-Circle a few paces to the north. Much labour was bestowed upon these observations, and about 6,000 mean places for 1860·0 were deduced; but owing, it is believed, to the discovery of certain systematic errors, they have not yet been published. There are besides, according to Professor Schering, about as many unreduced observations, and one cannot but join in the wish that these may eventually be utilised (see *Ast. Nach.*, No. 2573).

Klinkerfues was nominated Provisional Director of Göttingen Observatory in 1859, Extraordinary Professor of Astronomy in 1863, and eventually director of the Observatory for Practical Astronomy in 1868.

During these years of tardy advancement, Klinkerfues never managed to shake off the load of debt that oppressed him, and only to his singularly elastic and genial temperament can it be ascribed that he was still able to abstract himself from his troubles, and labour zealously in the enchanted field of original investigation. About 1864 he became absorbed in optical studies, more particularly in that of the refrangibility of light, as affected by the motion of its source, and the medium through which it passes. In these difficult investigations, his own experiments with an achromatic prism in 1865 led to no satisfactory results, although they were not without their value in directing attention to the subject, afterwards so successfully dealt with by the dispersive prism in the hands of Dr. Huggins and others. In like manner his imperfect experiments on the possible dependence of the constant of aberration on the thickness of the object-glass of the telescope employed, served but to prepare the way to the complete settlement of the question in the negative by Sir George Airy. About this time Klinkerfues published translations (into German) of Briot's "Essai sur la théorie mathématique de la lumière," and of Dr. Huggins' Nottingham lecture on Spectrum Analysis, as applied to the heavenly bodies. The latter passed through more than one edition; and in a much modified and expanded form, as a supplement to recent editions of Mädler's "Wunderbau des Weltalls," forms one of the most lucid elementary treatises on the subject.

In 1881 he rescued from oblivion T. Mayer's original lunar sketches, made about the middle of last century, a small number of copies of which were phototyped under the title of "Tobias Mayer's grössere Mondkarte nebst Detailzeichnungen," Göttingen, 1881; one of them is in the Society's library.

In his character of professor, Klinkerfues usually read three courses of lectures—on spherical, on theoretical, and on perturbational astronomy. In each of these departments his teaching was distinguished by the great variety of his methods of exposition. In his hands the most hackneyed subject assumed some fresh interest, or was regarded from some new and unexpected point of view. This is clearly exemplified in his published work, "Theoretische Astronomie," which will long remain a favourite work amongst students of astronomy. In this work the relation between shooting-stars and comets is dwelt on at length in a special section, in which the term "radiant of convergence" is introduced; hence, on the appearance of the great display of shooting-stars on November 27, 1872, Klinkerfues quickly came to the conclusion that the departing swarm of meteors ought to be visible in the neighbourhood of θ *Centauri*. How his telegram to Madras led to the observation by Mr. Pogson, on two occasions, of a cometic body in the region of the heavens indicated, is a part of the history of astronomy, although it is not universally admitted that the object so seen was associated either with the meteoric display, or with Biela's comet. Should the coinci-

dence, after all, have been only accidental, it would, indeed, be an occasion for the application of Schiller's lines, already quoted by Sir John Herschel in another connection—

> Mit dem Genius steht die Natur in ewigem Bunde,
> Was der Eine verspricht leistet die Andre gewiss.

Later on Klinkerfues devoted much care and thought to the improvement of the hair hygrometer, and eventually produced a bifilar instrument, of which the theory is as elegant as it is interesting. This instrument, when tested at even wide intervals, is calculated to be of great use whenever it is desirable to know the relative humidity of the air at a glance. An attempt to utilise this instrument in the local prediction of weather, notably of rainfall, was not without a considerable measure of success, although from the very nature of the problem its applicability to large areas may well be doubted. Other inventions, ingenious enough in themselves, served only to lead him into business engagements which he was totally unfitted to deal with.

Professor Klinkerfues' contributions to the daily journals ranged over a great variety of subjects, but all his papers were singularly readable, and often contained the most original and suggestive ideas. Occasionally, indeed, they were altogether of a quaintly humorous character, introducing, for instance, the alleged wonderful discoveries of an imaginary Professor Monkhouse, who read the past history of our globe in the reflections from the surfaces of the fixed stars. The Royal Society's Catalogue enumerates fifty-two of his scientific papers in addition to nine published in conjunction with J. G. Westphal. More than thirty years ago he was nominated corresponding member of the Academy of Antwerp, and was subsequently decorated with the Order of the Guelph by the late King of Hanover, at whose instance he observed the total eclipse of the Sun on July 18, 1860, at Cullera, in Spain.

It would be useless and almost impossible to attempt to describe how the warm-hearted and genial astronomer failed to take that position amongst his colleagues to which his undoubtedly great natural talents entitled him. His extreme carelessness of late years in his outward appearance was certainly much against him, but the unflagging zeal with which he delivered a whole course of lectures, if need were, even to a single student, ought to have told in his favour, as to some extent it doubtless did. But on one ground or other the title of *Professor ordinarius* was withheld from him to the last, although eventually the equivalent stipend was conferred upon him. Still the pleasure the official recognition of his ability would have afforded him may be gathered from the evident and warmly expressed satisfaction with which he regarded his election as Associate of our Society. But nothing could dispel the gloom that settled over him with the complete wreck of all his financial

plans, to which was added the load of failing health, perhaps mental as well as bodily, until at last he found in death a release from that life so fraught with care and anxiety. This took place on January 28th, 1884.

He was elected an Associate of this Society on November 10, 1882.

R. C.

Marian Kowalski was born at Dobrzyn, in the province of Plozk, on August 15, 1821.

He was the son of a Polish nobleman, and received his early education at the Gymnasium of Plozk, removing subsequently to Warsaw, where he was trained for an engineer. The prospect of success was not encouraging, and he therefore, in 1841, entered himself as a student at the St. Petersburg University. Being ignorant of the Russian language, though proficient in German, French, and Latin, he had many difficulties to contend with; but by giving private lessons, he managed to keep himself and a younger brother at St. Petersburg.

In 1845 he left the university, after receiving the gold medal for his essay on "The Principles of Mechanics." The next year he passed his Master's examination, and took his degree upon an essay "On the Perturbations of Comets," which he wrote in Russian. This essay was unfortunately never printed.

For the greater part of the year 1846 Kowalski lived and worked at the Pulkowa Observatory.

In the spring of 1847, the Russian Geographical Society sent an expedition, under the command of Colonel Hofmann, to explore the little-known region north of the Ural Mountains. Young Kowalski, who had obtained a reputation among the savants of St. Petersburg for his astronomical and mathematical ability, was appointed astronomer to the expedition, for the purpose of determining the position and height of the Ural Mountains between Tscherdyn in the Government of Perm and the Arctic Sea, to serve as a basis for charting the neighbouring rivers Ob and Petschora. Great difficulties were met with—climatic and otherwise—which permanently affected his health.

The results of this expedition were published in the first volume of "Der Nördliche Ural und das Küstengebirge Pae-Choi, 1883." In this work we find the positions of 186 stations laid down for astronomical observations, and the heights of 72 points in the Northern Ural Mountains, determined partly from trigonometrical and partly from barometrical observations.

Kowalski was requested by the St. Petersburg Academy of Sciences to undertake some magnetic observations during this expedition; and he succeeded in determining the magnetic elements of five stations in the extreme north, where he happened to stay. He also made many meteorological observations.

From these magnetic observations he made a mathematical investigation on "The Opposite Working of Two Magnets and

the Determination of the Horizontal Intensity of Terrestrial Magnetism," which was published in Russian in 1852.

In August 1850 Kowalski was appointed Assistant Astronomer at the University of Kasan. At this time he had already commenced his researches on the planet *Neptune*, which soon after brought his name into notoriety. In 1852 he published at Kasan a dissertation in Russian, "On the Motion of *Neptune*," and for this work and that on the Ural Expedition he was awarded the Demidowschen prize of the St. Petersburg Academy of Sciences. In this first paper on the motion of *Neptune* Kowalski gave the elements of the orbit derived from a limited number of observations. In 1855 he undertook a new investigation of the orbit, availing himself of all observations published up to 1853. This work, entitled "Recherches sur les Mouvements de *Neptune* suivies des Tables de cette Planète," was published at Kasan in 1855.

It consists essentially of two parts. In the first part the author investigates the corrections to be applied to the elements of the planet, taking into account the perturbations produced by *Jupiter*, *Saturn*, and *Uranus*. The materials which form the basis of this discussion consist of the early observation of the planet by Lalande in 1795, and all the accessible modern observations extending from 1846 to the close of 1853. The corrections applicable to Walker's elements of the planet published in 1847, from observations extending over a very small arc, are small.

The following are the definitive values of the elements obtained by Kowalski:—

Epoch 1850. Jan. 1, Greenwich Mean Noon.

Mean Longitude	$334^\circ\ 36'\ 29''.78$
Longitude of Perihelion ...	$50\ 16\ 39''.08 + 51''.014t$
Longitude of Ascending Node ...	$130\ 7\ 45''.30 + 39''.615t$
Inclination	$1\ 47\ 0''.89 - 0''.346t$
Mean Motion	$7873''.993$
Mean Distance	30.03386
Eccentricity	$0.0091736 + 0.0000000558t$

Professor Newcomb has shown, from a comparison of Kowalski's ephemeris with heliocentric longitudes derived from observations extending over a longer period, and using his perturbations, that the above elements require some small corrections.

The second part of Kowalski's memoir contains Tables of the planet founded on the corrected elements. In Table I. the author gives the heliocentric longitude and latitude and the logarithm of the radius vector for every thirty days throughout

the period extending from 1846 to 1880, with columns of differences for interpolation.

Table II. contains the value of certain of the subsidiary quantities depending on the heliocentric rectangular co-ordinates of the planet, by means of which, in connection with the Sun's rectangular co-ordinates given in the *Nautical Almanac*, the geocentric right ascension, declination, and distance of the planet may be found for every thirty days from 1850·0 to 1880·0. Professor Newcomb has, however, called attention (*Monthly Notices*, vol. xxv. p. 45) to certain errors in these Tables which prevent them from accurately representing the motions of the planet.

In 1851 Kowalski went with Professor Popow to Berdjansk, on the Sea of Azov, to observe the total eclipse of the Sun on July 28, the results of which appear in the publications of the Kasan University for 1851. In this expedition they fixed the geographical position of ten of the principal towns on the Volga, the longitudes being determined by means of fourteen chronometers, and the latitudes with a transit instrument.

On the retirement of Professor Liapounov, in 1854, from the direction of Kasan Observatory, Kowalski was appointed his successor.

In 1856 he published a paper in Russian on eclipses, in which he gave his own methods for the complete calculation of eclipses and occultations.

In 1859 three important papers by Kowalski appeared in the "Recherches Astronomiques de l'Observatoire de Kasan." The first one, entitled "Sur les lois du mouvement propre des Etoiles du Catalogue de Bradley," was devoted to a discussion of the question whether the proper motions, and consequently the true motions, of Bradley's stars were subject to other laws than those governing the motion of the solar system in space, and what deductions could thence be made with regard to the structure of the stellar system, and the forces which rule it. The discussion is based entirely upon Mädler's proper motions of Bradley's stars. The result arrived at is that there exists a zone of minimum proper motion, which crosses the equator at 111° 43′ and 291° 43′ of Right Ascension. These points are 10° removed from the points of intersection of the Milky Way and the equator. The pole of this zone is situated in Right Ascension 201° 43′ and North Declination 21°, which is not far removed from the pole of the Milky Way, as determined by Sir John Herschel, viz. Right Ascension 191° 45′, Declination +27°.

The remaining two papers, which constituted the only number of the "Recherches" ever published, were entitled "Sur le Calcul de l'Orbite elliptique ou parabolique d'après un grand nombre d'Observations," and "Développement de la fonction perturbatrice en série." A brief abstract of the last paper was published in vol. xxi. of the *Monthly Notices*.

After this period Kowalski does not appear to have devoted

himself much to theoretical astronomy. During his later years he was occupied in the observations of circumpolar stars between +80° and the Pole, which sedulously engaged him until 1869, when he joined in the zone observations of the "Astronomische Gesellschaft," undertaking the zone between +75° and +80° Declination. The reduction of these observations was completed in 1883, and the printing, which was then begun, has already made considerable progress.

Kowalski was endued with great energy and power for work, but characterised by a modesty which made him shrink from publishing his works until he had severely criticised them.

From the interesting account of his life given in the *Vierteljahrsschrift* of the "Astronomische Gesellschaft" we learn that Kowalski has left much valuable scientific work which has not been published. The ability and conscientiousness displayed by him in all his researches are an assurance that astronomy would be greatly enriched by their publication.

An affection of the heart, from which he had suffered for some years, suddenly terminated his life on July 9, 1884.

He was a corresponding member of the St. Petersburg Academy of Sciences, and honorary member of the St. Petersburg University.

He was elected an Associate of this Society on November 13, 1863.

Johann Friedrich Julius Schmidt, Director of the Observatory at Athens, whose death was briefly announced in the last Annual Report, was born at Eutin, in Oldenburg, on October 25, 1825. At a very early age his friends soon perceived that he possessed a great inclination for astronomical pursuits, and scarcely had he entered his teens before he gave decided indications of those talents for quickness and acuteness in observing which have marked his scientific career throughout his life. What perhaps encouraged young Schmidt at this early period more than anything else in his enthusiastic taste for the observation of natural phenomena, and more especially for those relating to the physical features of the lunar disk, was the accidental circumstance that when only fourteen years old a copy of Schroeter's work on the Moon, *Selenotopographische Fragmente*, came by some means into his possession. The perusal of this work produced on his mind an intense desire to study on his own account, at some future time, the various peculiarities of the shadow-throwing hills and craters; and to this early influence we must attribute the origin of that life-long devotion which he afterwards gave to the subject of selenography. Fortunately for the young student at this commencement of his career, his father happened to have a small low-power telescope, and with this instrument, attached to a lamp-post, Schmidt made, in 1839, his first attempts at sketching some of the more prominent craters and their surroundings. For a year or two he had no

other instrumental assistance; but imperfect as his telescope was, it afforded him much pleasure and increased his enthusiasm for lunar sketching. Nearly all his spare time was now devoted either to the examination of Schroeter's work or in observing with his small telescope, the mounting of which he had, however, soon improved by constructing for it a rough wooden stand, so that his observations were greatly facilitated. The lunar sketches young Schmidt had made with this small telescope at the beginning of his career were comparatively much rougher than the more finished drawings executed in later years under more favourable circumstances, but they were of great advantage to him at the time, for they were the means of giving him most excellent practice as a student, both in the education of his eye and in the power of delineating the more delicate portions of the Moon's surface. But Schmidt himself knew well that these early observations, having been made under many difficulties, and with so small a telescope, must naturally have been inferior to those made in after years, and he was therefore probably wise in ultimately rejecting them in the final formation of his lunar map.

Through the kindness of a gentleman who had noticed the youth's great zeal for astronomy, and that he was evidently encumbered with many practical difficulties, Schmidt procured, in 1841, the loan of a 4-feet Dollond Telescope, having a power of 15 to 20. This addition to his instrumental means enabled him to prosecute his researches with increased success. Soon after this he became a student at the Gymnasium at Hamburg, but at the same time he never failed to avail himself of every opportunity to continue his observations. This predilection for the study of lunar objects received a great stimulus during a visit, in the month of July 1841, to the Altona Observatory. Here, under the guidance of Dr. Petersen, Schmidt saw the Moon, for the first time, in a larger telescope. It was, therefore, at the Altona Observatory that he first obtained a fair notion of the wide field of inquiry still open to the observer of lunar objects; for not only was he captivated by the telescopic appearance of the craters of *Gassendi*, *Bullialdus* in the *Mare Nubium*, and other prominent objects which Dr. Petersen showed him, but he also had an opportunity of inspecting, also for the first time, the celebrated chart of Beer and Mädler, which in the future was destined to serve as what may be fittingly termed his working lunar catalogue. While a resident in Hamburg Schmidt was a frequent visitor at the Hamburg Observatory, when, through the courtesy of Dr. Karl Rümker, the instruments were occasionally placed at his service for the prosecution of his lunar observations. This permission proved to have been a great boon to the young student, as it enabled him, when necessary, to view the details on the Moon's surface with a higher power than that to which he was usually accustomed.

In 1845 Schmidt, then about twenty years of age, left Hamburg

to accept the appointment of assistant to Professor Benzenberg, who had established an Observatory at Bilk, near Dusseldorf, principally for the purpose of observing occasional astronomical phenomena, but more particularly of shooting-stars and other naked-eye objects, a class of observation in which Schmidt, as well as Benzenberg, was at the time specially interested; and also for the systematic search for supposed intra-Mercurial planets, a subject suggested by the recent publication of Le Verrier's researches on the theory of *Mercury*. Schmidt's lunar observations at Bilk were, however, of a negative character, for during his connection with that Observatory he was able to make only a very slight progress in his sketches of the Moon. This partial cessation of his favourite employment was not owing to any relaxation of energy on the part of Schmidt, but rather to the inferior instrument placed at his disposal for his own peculiar work; for it has been stated that Professor Benzenberg was so careful of his principal telescope that he feared that its outward good looks and polish would suffer had he permitted the young ardent astronomer to use it. Schmidt's connection with the Bilk Observatory was, however, very short, as on the death of Professor Benzenberg in the following year he transferred his services to the Bonn Observatory, where he remained under the direction of Professor Argelander till the year 1853. While an assistant at Bonn, Schmidt made good progress with his lunar researches, without neglecting the usual duties of the Observatory. In these he took his regular share of work, including observations of the positions of small stars for insertion in Hour V. of the Berlin Academy star-charts, as well as of new planets and comets and their comparison stars. Among the comets observed by Schmidt at this time we may refer to the observations of those of Mauvais and Brorsen, published in the *Astronomische Nachrichten* for 1848, and of Petersen and Goujon in 1849. Besides these comets he observed many others, the results of which have been communicated from time to time to the same periodical, including observations of the comets of Klinkerfues and Bruhns. A very important series of drawings of *Saturn* was made by Schmidt in 1848, at the time of the Saturnian equinox, consisting of seventeen sketches of the planet at about the time of disappearance and reappearance of the rings, the principal features in which indicated the possible existence of great inequalities of surface on the rings not previously observed. He also, while at Bonn, formed one of the German party of astronomers who selected Eastern Prussia as their place of observation of the total solar eclipse of July 28, 1851. His account of the eclipse was published at Bonn in 1852 under the title of "Beobachtung der totalen Sonnenfinsterniss zu Rastenburg," extracts from which may be found in Mr. Ranyard's collation of the observations made during total solar eclipses contained in the Society's *Memoirs*, vol. xli.

On the recommendation of Professor Argelander, Schmidt

was appointed in 1853 to take the direction of the Baron von Unkrechtsberg's private Observatory at Olmütz, in Moravia, where he continued his sketches of the lunar features—craters, rills, mountain ranges, &c.—accompanied by numerous micrometrical measurements. Here he remained till 1858. During a visit to the south of Italy in the months of March and April 1855, he took that opportunity of making special lunar drawings, first with the great Refractor at Rome, and afterwards at the Observatory at Naples.

On December 2, 1858, Dr. Schmidt entered upon his duties as director of the Observatory at Athens, where he remained in full activity as an astronomical observer of great reputation to the end of his life. He found this slightly-endowed Observatory in far from flourishing circumstances, and some time elapsed before he was able to bring the 6-feet Refractor by Plössl into a satisfactory adjustment. This preliminary work occasioned some unavoidable delay in his lunar researches, now far advanced; but when his instrument was brought again into working order, he soon made considerable progress, though a large portion of his observing time was devoted to the observation of variable stars, comets, meteors, and other miscellaneous phenomena, of which the resulting observations have been usually printed in the pages of the *Astronomische Nachrichten*. Some of Schmidt's cometary observations have, however, appeared in his "Astronomische Beobachtungen über Cometen," which forms Series 1, vol. i. of the "Publications de l'Observatoire d'Athènes." The results of his observations of extraordinary meteors were, in 1867, published in an octavo volume, entitled "Ueber Feuer-Meteore, 1842 bis 1867." During the latter period of his lunar researches, knowing that the end of his preparatory labours, in anticipation of the formation of his long expected chart, was now approaching, most of Dr. Schmidt's time was devoted to the re-examination of what he had already done, and in filling up those portions of the chart which had hitherto been neglected, a work which necessarily occupied several years. At the same time he was always ready to pick up any new object visible to the naked eye, for he was a constant watcher of the heavens, and a new star or comet was rarely known to appear suddenly without its being soon detected by the keen and sensitive eyes which he was known to possess. In illustration of his knowledge of the constellations, as well as of his watchfulness, we need only refer to his early independent detection of the outbursts of the interesting variable stars T *Coronæ*, which suddenly appeared in May 1866, and *Nova Cygni*, which as suddenly became visible to the naked eye in November 1876. The former variable was observed first by Mr. Birmingham on May 12, and secondly by Dr. Schmidt on the following day; while the latter was first noticed by Schmidt, who made almost daily comparisons of its relative brightness from the day of the discovery of the outburst, November 24, to the middle of December, the magnitude

of the star during this period of three weeks having gradually diminished from the third to the seventh. This continuous series of comparisons of *Nova Cygni* was a very important one, as owing to some delay in making the outburst known to other observers, coupled with cloudy weather, Dr. Schmidt was the only person who had the good fortune to witness the star when at, or near, its maximum brilliancy.

Among the various astronomical labours of Dr. Schmidt, his celebrated chart of the Moon, for the most part completed in 1868, though not finally revised till July 1874—thirty-five years after his youthful determination in 1839 to undertake so extensive a work—will ever remain as the most permanent memorial of the great patience and energy displayed by him throughout this long period, which eventually enabled him to present to his astronomical colleagues this important contribution to selenography. Excellent, however, as the chart is, it would not be correct to say that it is perfect; on the contrary, many serious defects may be easily pointed out, including unavoidable faults arising from the reproduction of the chart by means of photo-lithography, a process that would effectually perpetuate all roughness of drawing, the defects of handwriting, or any injury that might have been caused to the delicate portions of the chart after the eight or nine years' working of Schmidt at the sections. In fact, the parallel and meridian lines on the map were obliterated by this cause, and an attempt was made in 1874 to restore them, but owing to the roughness of the surface of the paper, it was found that this could not be done satisfactorily. From the absence of these lines it is not possible to determine the exact positions of the different objects, which can only be inferred approximately from the graduations on the margin of the map. The photo-lithographic copies also show very clearly that the fainter portions of the lunar markings are greatly exaggerated, for there is not much distinction between the relative intensity of these and the darker mountainous ranges. This important defect becomes very apparent on comparing one of the sections with the corresponding one in Lohrmann's chart, which has been engraved on copper-plate. But, notwithstanding these and other serious blemishes, the whole chart as it stands, with its volume of descriptive text, still remains as a most creditable production by one person, though it be the result of a life-long labour. Dr. Schmidt, in the title to his work, names the map as a chart of the lunar mountains. It is divided into twenty-five sections, each complete in itself, with the usual graduations at the edges, to make it more convenient for reference to the positions of the various objects.

For some time before the completion of the chart, rumours were circulated among astronomers that it was very doubtful whether the results of all this labour of Dr. Schmidt would pass out of the manuscript form, owing to the small endowment of the Athens Observatory. It was evident that the Observatory

had no funds available to bear the expense of publishing the map in its entirety. But it was the opinion of many of those most interested in lunar work, that the chart ought to be in the hands of astronomers generally as soon as possible. On this ground the subject of finding means for its publication in England was discussed by a few of the Fellows of the Royal Astronomical Society, who were also very desirous that the results of Dr. Schmidt's labours should not be lost to the science. He was accordingly requested to forward an estimate of the probable expense of transferring the map upon stone by photo-lithography, or by any other method. Dr. Schmidt, however, proposed pecuniary conditions which, under the circumstances, were impossible to be entertained, and thus the question of publishing the chart in England was given up with regret. Fortunately for science, Dr. Schmidt, during a visit to Berlin in 1874, exhibited his chart at the Observatory, where it excited much admiration among scientific men, which eventually resulted in arrangements being made for its publication under the auspices of the Prussian Government. The Crown Prince was much impressed with the appearance of the chart, and used his influence in its favour with success. It was decided by the authorities that the twenty-five sections, of which the map was composed, should be photo-lithographed at the General Staff Office, under the direction of the Count von Moltke, from the original drawings of the chart as finally completed by Dr. Schmidt. The work was published at Berlin in 1878, under the title of "Charte der Gebirge des Mondes nach eigenen Beobachtungen in den Jahren 1840–1874. 25 Sectionen und Erläuterungsband," folio and quarto, containing the results of a series of more than a thousand drawings, and three times that number of measures of heights, omitting, as we have before stated, most of the sketches made previously to 1842, as these were not employed in the construction of the chart, on account of the first few years' observations having been considered by Dr. Schmidt to be comparatively imperfect. In addition to Schmidt's own lunar work, he also found time to prepare for publication Lohrmann's "Mondcharte in 25 Sectionen," of which only four had hitherto been published in the first part of Lohrmann's work. The unpublished sections came into his possession in an incomplete state many years ago, when he at once announced his intention of publishing them. But, owing to his time having been fully occupied on the revision of his own chart, he was unable to complete them for publication till 1875, which is the date given at the end of the preface. To this work he contributed the descriptive text, consisting, however, only of a very brief statement of the formations included in the sections. It was published at Leipzig in 1878.

The following extract from an interesting review of Dr. Schmidt's labours, written in 1879 by the late Mr. Birmingham, of Tuam, gives in few characteristic words an epitome of the difficulties and successes experienced by the distinguished astro-

nomer. It will form an appropriate conclusion to our brief remarks on his lunar researches: "In even a cursory examination of Schmidt's map, its completion by a single observer must seem almost incomprehensible to a man of ordinary powers; but it requires protracted study to well realise the extent of the work. Any person who tries with the aid of a six-feet telescope to give closely detailed delineation of even a small area of the Moon, will soon conclude that the period of thirty-three years was comparatively a very short one for the accomplishment of Dr. Schmidt's great task. It is, in all truth, a performance highly creditable to the age in which we live, and to Teutonic intellect and perseverance. It is a splendid example from small beginnings. We have first, the astronomer, as a youth of fourteen, viewing the Moon with a little telescope, steadied by a lamp-post, and probably the laughing-stock of many a passer-by; afterwards he is found, in maturer years, pursuing his favourite study under more or less difficult circumstances and in different countries, until, at length, as director of a national Observatory, he completes the wonderful production of his truly inimitable labours. For this it required all the unswerving persistence that is ever a chief attribute of genius; and the pages of the *Astronomische Nachrichten* and other scientific publications can testify to the large amount of other astronomical work performed by Dr. Schmidt simultaneously with his lunar researches." (*The Observatory*, vol. iii. p. 16.)

Of Dr. Schmidt's miscellaneous astronomical observations, it is not necessary to say more in this place than that he was an indefatigable observer of double stars, variable stars, nebulæ, Sun-spots, the markings on the surfaces of the planets and the times of their rotation, meteors, the zodiacal light, and the physical appearances of comets, of which those of Brorsen, Tempel II., and Encke, described in the *Astronomische Nachrichten* for 1868, may be specially referred to. Dr. Schmidt's papers in this astronomical journal extend over a period of forty years, the title of the first memoir inserted in the Royal Society *Catalogue of Scientific Papers* to 1873, being "On the Periodicity of the Variable Star δ *Cephei*," contained in vol. xxi. for 1844. In this Catalogue the titles of 138 papers are given. In the ten following years this number must have been very considerably augmented.

Dr. Schmidt was admitted an Honorary Doctor of the University of Bonn, on the occasion of the foundation festival held in 1868, and he was elected an Associate of the Royal Astronomical Society on January 9, 1874. He continued in the full activity of his labours, and retained his character for acuteness for observing to the last. The same number of the *Astronomische Nachrichten* which contains the results of his last observations of variable stars, made during the year 1883, also gives his obituary notice. Dr. Schmidt had attended a reception at the German Embassy, at Athens, on the evening of Wed-

nesday, February 6, 1884, apparently in his usual health. On the morning of February 7 he was found dead in his bed, having expired suddenly some time during the night. Universal regret was expressed throughout the city on the announcement of his sudden death, and his funeral was fitly made one of national mourning, the King and Queen of Greece attending at the Observatory during the delivery of the funeral oration. At the time of his death Dr. Schmidt was in the fifty-ninth year of his age. E. D.

Proceedings of Observatories.

The following Reports of the proceedings of Observatories during the past year have been received by the Council from the Directors of the several Observatories.

Royal Observatory, Greenwich.

The regular meridian observations of the Sun, Moon, planets, and selected stars have been continued in the past year, the whole number of transits observed in 1884 being 5,362, and of meridian zenith distances 4,758. About 1,520 stars were observed in the course of the year, and as the working catalogue is now nearly cleared off, a new list of about 380 stars of the sixth magnitude, which had been omitted, has been incorporated with it. In the preparation of this list use has been made of the recently published "Harvard Photometry," with a view of making the forthcoming Greenwich catalogue of stars down to the sixth magnitude as complete as possible.

In order to determine the personal error depending on the direction of measurement or of motion relatively to the observer, a "reversion-prism," as used by Mr. Gill, has been adapted to the Transit Circle and the collimators. In the determination of collimation error, the difference in the results has been found to be in every case insensible when, by means of the reversion prism, a movement of the wire towards the right is apparently converted into a movement towards the left, or upwards or downwards; but in the observations of transits there appears to be a well-marked personality depending on whether the star's apparent motion is towards the left or towards the right. It is to be remarked, however, that the observers have not yet had sufficient practice in the observation of the reverse motion for quick-moving stars to admit of trustworthy determination of their personal equations in these novel conditions.

The chronograph has lately required cleaning and general repair, and Messrs. E. Dent & Co. have taken advantage of the opportunity to make various alterations suggested by experience. The transits since January 7 have therefore been observed by eye and ear, and materials are thus being obtained for a determination of personal equations in eye and ear transits.

Since last October transits of the close circumpolar stars have been taken at the middle wire set to successive revolutions

of the R.A. micrometer instead of at the successive wires of the chronographic system, the intervals of which are not close enough to allow of a sufficient number of separate observations being obtained in a moderate time. The equality of successive intervals of the R.A. micrometer screw has been recently tested by means of the south collimator for each revolution through a range of twelve revolutions, and also for every tenth of the three middle revolutions, and the errors of the screw are found to be less than the uncertainty of the determinations.

The mean error in R.A. of Hansen's Lunar Tables with Professor Newcomb's corrections is $+0^{s}\cdot02$ for the year 1884, as deduced from 104 observations with the Transit Circle.

The flexure of the Transit Circle, as found by means of the collimators, has again apparently changed sign. The resulting value from five determinations in 1884 is $+0''\cdot18$, agreeing closely with the mean of the values found in the period 1879 to 1882, whilst the mean of five determinations in 1883 gave the value $-0''\cdot49$. No flexure correction has been applied since the beginning of 1879. The apparent correction to the Nadir observation indicated by the mean of reflexion observations of stars in 1884 is $-0''\cdot36$, being slightly less than for the previous year.

The observations of the Moon with the Altazimuth have, as before, been confined to the first and last quarters in each lunation. A reversion-prism has also been applied to this instrument.

With the Reflex Zenith-tube, the observations of γ *Draconis* for determination of the temperature correction have been continued, and 39 transits have been observed at temperatures ranging from 57° to 72°.

The dome for the Lassell Equatorial was completed by Messrs. T. Cooke & Sons at the end of last March, but the instrument has only recently been got into working order, as a number of repairs and alterations were required, which have necessarily occupied much time. Amongst other things an improved edge suspension of the mirror has been contrived. This consists of a steel band encircling the edge of the mirror, and supported by brackets at six equidistant points of its circumference in such a way as to distribute the strain whatever part of the mirror may happen to be lowest. Unfavourable weather and difficulties with the driving clock, slow motions, &c., have so far prevented our obtaining any satisfactory micrometer measures of the satellites of *Saturn* with this instrument.

Comet (*c*) 1884 has been observed on four days, the Lassell Reflector or one of the other Equatorials being employed, and some measures of distance and position-angle of double stars, as well as a large number of observations for determining the value of one revolution of the screw in different parts of the field, have been made with the Airy Double-image Micrometer, mounted on the Sheepshanks' or Simms' Equatorial. Twenty-

two occultations of stars by the Moon (including seven disappearances and nine reappearances of faint stars, observed with five different instruments during the lunar eclipse of October 4) and 51 phenomena of *Jupiter's* satellites have been observed during the past year. The occultation of *Venus* by the Moon on February 29 last was observed with two instruments.

The following spectroscopic observations have been made with the Half-prism Spectroscope mounted on the S.E. Equatorial:—674 measures of the displacement of the F line in the spectra of 48 stars; 49 of the *b* lines in the spectra of 12 stars, eight of the F line in the nebula of *Orion*; together with 132 comparisons of the hydrogen or magnesium lines with the corresponding lines in the spectrum of the Moon, or of the sky, several measures of the displacement of the F and *b* lines in the spectra of *Venus* and *Mars*, and some observations of the relative displacement of the F and *b* lines at the E. and W. limbs of *Jupiter*, as a check on the general accuracy of the results for star motions.

In April last the photoheliograph was adapted, by means of a new secondary magnifier (similar to that applied to the instrument at Dehra Dûn), to take photographs on the scale of 8 inches to the Sun's diameter. These large-scale pictures are found to be quite as satisfactory in regard to definition as those of 4 inches, and show much more detail of the Sun's surface.

In the year 1884, 445 photographs were taken at Greenwich on 156 days, the record being not so complete as usual, owing partly to the loss of several days during the adaptation of the new secondary magnifier and subsequent adjustment of the instrument, and partly to a failure of the supply of dry plates in July last. The Greenwich photographs have been supplemented by photographs received from Dehra Dûn for the period 1884 January 1 to November 28, thus making a total of 281 days out of 334 days on which we have photographs available for measurement.

The maximum of solar activity, both in Sun-spots and faculæ, appears now to be definitely past, and the same may be said of magnetic activity, which has been much less marked in 1884 than in either of the two preceding years.

The reductions of all the above-mentioned observations are in a very forward state.

The volume of "Greenwich Observations" for 1882 was distributed in June last, and the printing of the astronomical portion of the volume for 1883 is complete, with the exception of the Introduction. The printing of the Photographic Results, as well as of the Magnetic and Meteorological Results, for 1883 has been somewhat delayed by some additional investigations, but it is now well advanced.

On January 1 the public clock and other mean solar clocks were put forward twelve hours so as to show Greenwich civil

time starting at midnight, and reckoning from 0^h to 24^h, which would correspond with the Universal time recommended by the Washington Conference. The change from astronomical to civil reckoning has also been made in all the internal work of the Observatory, and has been carried out without any difficulty. Greenwich civil time is found to be more convenient on the whole for the purposes of this Observatory, but in the absence of a general agreement amongst astronomers, it has so far been only adopted provisionally, and has not yet been introduced into any printed observations. The change from civil to astronomical reckoning is so easily made that we are quite prepared to use the old or the new time in the "Greenwich Observations, 1885," as may be judged most expedient when the printing of these observations is commenced at the beginning of 1886.

The Observatory has during the past year lost the valuable services of Mr. Dunkin, who retired on August 25, after an honourable connection of forty-six years with the Royal Observatory. Mr. Dunkin has been succeeded in the post of Chief Assistant by Mr. H. H. Turner, B.A., of Trinity College, Cambridge.

Armagh Observatory.

It was announced, in last year's report, that the Lords Commissioners of the Treasury had inserted on the estimates for the year the sum of 2,000*l.* as a grant towards the maintenance of the Armagh Observatory. The grant was paid in August last, the Governors having previously executed a declaration of trust, pledging themselves to spend at present only 1,000*l.* on a new instrument, and to allow the remaining 1,000*l.* to accumulate until the original sum of 2,000*l.* had been recovered, after which time the interest of the whole amount may be spent at the discretion of the Governors for the purposes of the Observatory.

It had at first been intended to order a "Siderostatic Telescope" of the construction indicated about a year ago by Mr. Grubb, but as it was impossible at the same time to procure a second instrument to observe the northern part of the heavens (which would be out of reach of the Siderostatic Telescope), the idea was reluctantly abandoned, and a 10-inch Equatorial Refractor, of Mr. Grubb's well-known form, was decided on as meeting every requirement. It will be erected in a detached building of iron and wood, 15 feet in diameter, surmounted by a dome of iron framework, covered with papier-mâché. The expense of the dome will be borne by a fund subscribed two years ago to erect a scientific memorial to the late Dr. Robinson. The foundation of the building and the pier of the instrument

were built last autumn; the dome is to be ready in April next, the telescope in June.

The new catalogue of stars is going through the press.

Cambridge Observatory.

The number of transits observed with the Meridian Circle during this year amounts to 3,195, most of which were observed at five or seven wires, and all were read off with the four microscopes of the West Circle. These include 2,433 observations of stars, nearly all of which are in the zone between 25° and 30° of North Declination; 611 observations of Clock Stars, and 151 observations of *Polaris*, 73 of which are above the Pole and 78 below. *Polaris* is usually read off three times at each transit—viz., near the first wire, near the centre wire, and near the last wire, thus furnishing a good determination of the inclination of the wires.

In addition to these the requisite number of observations were made for level and collimation, and for obtaining the Nadir point. All this has been the work of two observers, with occasional help from a third.

One of the observations of the Nadir point was interrupted for a while by a singular circumstance. On the morning of April 22 Miss Walker had prepared to make the observation, and was looking into the eye-piece, when she perceived that the image of the wire, instead of being steady, was making violent oscillations. She found it necessary to wait for several minutes before the image became sufficiently steady to allow the observation to be made. It was not till afterwards that she was made aware that a slight earthquake shock had taken place at the exact time when she was attempting to make the observation.

To obtain a more accurate determination of the errors of division of the West Circle in the transit, an extensive series of comparisons with the East Circle was made in June, October, November, December 1883, and in January and February 1884. The East Circle, which is movable relatively to the tube, was clamped at each single degree throughout the quadrant, and its readings in each of the ninety positions were compared with the readings of the West Circle when the telescope was pointed to the Pole, to the Zenith, to the positions of *Polaris* above and below the Pole, to every fifth degree southward from the Pole up to 85° Polar distance, and to each single degree between 60° and 65° N.P.D., the limits of our zone. The largest relative errors were found to be at 15° and 50° N.P.D., where the readings of the West Circle require to be diminished by almost exactly 1″, supposing the reading at the Zenith to be correct. The greatest positive correction on the same supposition is at 85° N.P.D., where the mean of the microscopes ought to be increased by 0″·4.

The standard stars are completely reduced up to the end of 1883, and the coefficients for instrumental correction are obtained near the end of 1884. The reductions of the other stars are progressing satisfactorily.

Fourteen observations of the Comet Wells, made in May 1882 with the Transit Circle, were completely reduced, and the places forwarded to Dr. E. von Rebeur, of the Carlsruhe Observatory, who is engaged on an investigation of the orbit. He was also furnished with places obtained by comparisons of the comet with neighbouring stars, by means of the Northumberland Equatorial.

Two stars required by Professor Newcomb, in his determination of the mass of *Jupiter* from the motion of *Polyhymnia*, were found in the Cambridge zones; one observed twice, the other three times.

Of three stars required by Mons. Bossert, of the Paris Observatory, by letter dated 1884 October 29, two were found in the zones; one observed twice, the other once.

The places of ten stars, compared with Pons' Comet, were furnished to Mons. L. Schulhof on 1884 December 11.

Dunsink Observatory.

The fifth part of the *Dunsink Observations and Researches* has been issued to astronomers during the past year. It contains: I. Observations in Search of Stars with an Annual Parallax. II. Further Researches on the Parallax of 61 *Cygni*. III. On the Annual Parallax of Groombridge 1618. IV. On the Annual Parallax of P III. 242. V. On the Annual Parallax of 6 *Cygni* (B).

During the past year the Meridian Circle and chronograph have been devoted to the observation of southern stars included between 2° and 23° South Declination.

The majority of the stars on the working list still requiring observation when the year commenced were situated in the summer portion of the heavens, and, owing to the cloudiness of the weather in general during the summer months, most of these have again eluded observation, and the latter part of the year has been chiefly devoted to filling up gaps at long intervals in the working list.

The number of Right Ascensions observed is 343, and of Declinations 323; all of which, except a few of the more recent ones, have been reduced to their apparent places for the date of observation.

The clock correction has been determined by observations of standard stars from the *Berliner Jahrbuch;* and of these, 258 transits have been observed, the zero of Declinations being on every occasion determined by Nadir observations from a mercury

trough. The Nadir point has been thus determined 132 times, the errors of runs 78 times, the collimation error 144 times, and the level error 94 times.

The stars observed from September 1882 to March 1884 have, during the year, been reduced to their mean places, and the reduction of the observations made since the latter date is proceeding.

In addition to those mentioned above, when possible, observations were made of transits of standard stars to determine the clock error in connection with the time service to Dublin.

During the total lunar eclipse of October 4, observations of fourteen occultations were made with the south Equatorial in connection with the chronograph. Owing, however, to the invisibility of the dark part of the disk till the moment of total obscuration, it was possible to observe only two stars both at immersion and emersion. The results of these observations have been sent to Professor Otto Struve, but have not yet been published.

Royal Observatory, Edinburgh.

During the past year, true time, as obtained by star observations with the transit instrument, has been distributed from this Royal Observatory, daily, by electric time-ball, time-gun and controlled clocks.

The bi-diurnal observations at fifty-five stations of the Scottish Meteorological Society have also been computed here, and the results arranged for the Monthly and Quarterly Reports printed at regular intervals by the Registrar-General of Births, Deaths, &c., in Scotland.

A correspondence with the Government has been commenced by the Royal Society of Edinburgh, on the subject of printing the remaining portion of the Edinburgh Star Catalogue, but at present without any result.

Glasgow Observatory.

The operations at the Glasgow Observatory during the past year have been chiefly devoted to observations with the Transit Circle of a select list of telescopic stars suspected of proper motion. It is intended hereafter to devote more of the time available for observing purposes to operations with the Equatorial. Due preparations were made for observing the total eclipse of the Moon of October 4, in accordance with the terms of a letter relating thereto received from M. Otto Struve previous to the occurrence of the phenomenon; but the carrying of the project into effect was entirely frustrated by the unfavourable state of the weather.

Kew Observatory.

The sketches of Sun-spots, as seen projected on the photo-heliograph screen, have been made on 185 days, in order to continue Schwabe's enumeration. Spots were found on the Sun's surface on each of the above days.

A few experiments were made in June with the photo-heliograph, with a view of testing the suitability of certain plates prepared by Messrs. Morgan & Kidd for solar photography. With this exception nothing has been done in that branch during the year.

Transit Observations.—Frequent observations of both solar and sidereal transits have been made, for the purpose of keeping correct local time at the Observatory.

By the courtesy of Mr. Preece, Superintendent of Telegraphs, the Richmond Chief Post Office was placed in direct communication with the Royal Observatory, Greenwich, on January 22, and enabled to receive the time signal at 10 A.M., when a period of cloudy weather had rendered the true time a little uncertain. Two chronometers conveyed to the Post Office showed, on comparison with the signal, a satisfactory agreement between the times as kept at the two Observatories.

Two additional mean time clocks have been obtained, one of them, a Transit of *Venus* Expedition Clock, Dent 2011, has been lent to the Committee by the Astronomer Royal; the other has been purchased.

The superintendent, after communicating with the directors of the Geneva and the Yale Observatories, prepared a circular specifying the conditions watches must fulfil in order to obtain certificates of the various classes, A, B, and C, which are issued, and the nature of the test to which they will be subjected. This circular, together with the forms of certificates, &c., after revision and approval by the Committee, was printed, and copies forwarded to all the leading watch manufacturers of this country, as well as to the principal journals, many of which very favourably noticed the scheme.

Rating commenced on May 13, and up to the present sixty-six watches have been tried, of which twenty-five were submitted by the owners, and forty-one by the manufacturers or by dealers.

Certificates have been awarded to twenty-three of these watches, and nineteen are now on trial.

The usual magnetical and meteorological observations and reductions, and also the verification of instruments, operations to which the attention of the Observatory is mainly directed, have been carried on as formerly.

Liverpool Observatory, Bidston, Birkenhead.

The meteorological observations, the astronomical observations for time, the daily comparisons of the solar with two sidereal clocks by coincident beats, the communication of time to the port, and the daily comparisons of all the chronometers at the Observatory with the Normal clock, have been carried on in the same way as during former years.

For many years past special attention has been paid to the performance of chronometers with the view of showing the degree of accuracy with which Greenwich time can be carried on by them at sea, when an intelligible and systematic record is kept. During the past year records of the performance of the chronometers on twenty-six more voyages from Liverpool to Valparaiso and back again to Liverpool have been received at this Observatory.

The records from upwards of two hundred voyages of the Pacific Steam Navigation Company's steamers have now been obtained, and there is not a single instance in which failure of performance in the chronometers can have caused any inconvenience of importance. By the method which has been devised for calculating the errors from rates corrected for change of temperature, and the checking of these errors from time to time by land observations, the Greenwich time appears to have been nearly as well known from day to day as the local time at ship could be obtained. The navigating officers appear to take great interest in this method of keeping a record of the performance of their chronometers at sea. On bringing his timekeepers to the Observatory, one of them recently pointed out that by his three chronometers and the time signals at Rio Janeiro and Liverpool, the Lisbon time signal was wrong ten seconds. On examining the records with him at the Observatory it was found that the correct longitude had been used in his calculations for Rio, but through some oversight the old longitude, as given in the *Nautical Almanac* for 1883, had been used for Lisbon, thereby causing an error of $8^{s}\cdot6$. On this correction being applied the longitude obtained from the time signal at Lisbon differed from that obtained from the chronometers by only $1^{s}\cdot4$.

A report on finding the Greenwich time at sea, giving the results for each of three chronometers for one hundred voyages, and containing an example showing for one voyage how the daily records were kept, and how the calculations for change of temperature were obtained, has been published by order of the Mersey Docks and Harbour Board, for distribution amongst mariners. A copy of this report may be obtained by application to the director of this Observatory.

When, a few years since, the formula for calculating the corrections for change of temperature was published it was thought

that nothing further would be required from this Observatory than to supply the necessary data for making the calculations. Subsequently, however, it was found to be desirable that these calculations should be made at the Observatory and the navigating officers instructed in the method of applying the corrections at sea. The Mersey Docks and Harbour Board have allowed this to be done in order to make the subject known, and to show the advantage to be derived from applying corrections for thermal error in chronometric navigation.

Radcliffe Observatory, Oxford.

The Transit Circle has been in regular use throughout the year 1884. The number of observations is as follows:—

Transits	3,133
Circle observations (each requiring the reading of the four microscopes)	3,015

These totals include:—

Observations of the Sun	103
Observations of the Moon	62
Reflexion observations of stars	57
Nadir observations	381

Two observations were made of the time of passage of the Moon's diameter, and ten measures of the vertical diameter were secured in the year. The N.P.D. reductions are finished to the end of the year; the R.A.'s are completely reduced to May 31, the remainder being in a very forward state.

The volume of results for 1881 has been printed and distributed. The copy for press for 1882 is in the hands of the printer, and some proof sheets have been received and read.

The observations for 1883 are being discussed and prepared for press.

The discordance between reflexion and direct observations continues small; and determinations of Nadir reading taken over a range of the screws of more than five minutes of arc show that no serious errors can be introduced into our results from any existing wear in the screws.

The observations of the Moon have been compared with the Right Ascensions and North Polar Distances of Hansen's Lunar Tables, which have been interpolated for the purpose from the *Connaissance des Temps*. The mean excess of Hansen's Tables in longitude over observations, with the mean times computed in the usual way, is $+14''\cdot645$.

Six occultations of stars by the Moon have been observed, in addition to a series of occultations of faint stars during the total

eclipse of the Moon on October 4, observed in concert with other Observatories.

Nineteen observations of phenomena of *Jupiter's* satellites have been made with the extra-meridional instruments.

A telescope by Tulley, with a very good $3\frac{1}{4}$-inch object-glass, originally given by Sir James South, F.R.S., to the late Duke of Marlborough, has been presented to the Radcliffe Observatory by her Grace the Dowager Duchess as a memento of the Duke's long connection with the Institution as a trustee.

Oxford University Observatory.

During the twelve months which have intervened since the last report, the attention of the staff of this Observatory has been directed almost solely to the photometrical work which has there been undertaken. Out of the stars contained in Argelander's "Uranometria Nova," and not extending much lower than the equator, the relative lustre of only a few now remain to be measured, and these it is expected will be completed by the ensuing Easter.

In the course of this work it became desirable to ascertain the amount of light transmitted through various specimens of glass, or reflected from speculum metal, or from chemically deposited silver, or finally from the surface of glass itself. The results are very interesting as bearing on the relative light capacities of refracting and reflecting telescopes; and the interest is still further increased by the fact that the comparison light is in these investigations an actual star, and not an artificial star formed by the agency of a lamp. Some of these results have already been printed in the *Monthly Notices*, and the remainder are ready for communication to the Society.

The Wedge photometer appears to lend itself readily to the prosecution of such inquiries; and the experience of many thousands of measures made by it has confirmed the expectation of their accuracy, and of the facility of repeating with much exactness measures of stellar lustre made at distant intervals of time.

The research into the existence of evidence of gravitational action among the stars constituting the group of the Pleiades has now been printed in Part II. vol. xlviii. of the *Memoirs* of the Society, and will be published in due course.

The preliminary arrangements for determining with considerable accuracy the co-ordinates of the best known points on the Moon's surface have been completed. In addition to Ptolemy A and Triesnecker B, the positions of which are already given in the *Memoirs*, vol. xlvii., the following six formations have been selected as points of the first order, in respect of accuracy of position—viz. Hypatia B, Posidonius, Pico, Milichius A, Nubium C, and Fracastor E; and to these points as

origins of co-ordinates many other formations will be referred. The work is laborious, and will occupy considerable time.

On the roof of the lecture-room attached to the University Observatory, and originally prepared by the architect for this express purpose, a small subsidiary Observatory has been erected, containing a fine Altazimuth by Simms, and a refracting telescope of $4\frac{1}{4}$ inches aperture, by Cooke, completely furnished with subsidiary apparatus. These are intended for the use of the University students, for whom the larger Equatorial instruments under the domes were found for educational purposes to be too unwieldy.

The director has in every way been ably seconded by the intelligent diligence of the two assistants, Mr. Plummer and Mr. Jenkins.

The Temple Observatory, Rugby.

During the year 1884, the measurement of position and distance of binary and suspected binary stars has been continued; 264 sets of measures of 108 selected stars have been made.

The measures taken during the last four years have been reduced and prepared for printing and will be printed in Part II. of vol. xlviii. of the *Memoirs*.

The Observatory has been opened on 77 nights in the course of the year for the purpose of instruction, which of course has precedence of other work.

Some few measures of the motion of stars in the line of sight have been made with the spectroscope on the Reflector.

Stonyhurst College Observatory.

Besides the usual self-recorded meteorological and magnetic phenomena, which have suffered no interruption from the changes made at the Meteorological Office, the astronomical results are more numerous than in previous years. The Sun has received the most attention, in order that the rapidly changing phenomena of its surface may be studied with the greatest accuracy. A paper on this subject was read at the meeting of the American Association at Philadelphia. Two hundred and eighty-one drawings of the entire solar disk were made during the year on 257 different days, and supplementary observations on ten other days. The chromosphere has been measured on eighty-eight days, and partially observed on five other occasions. On thirty days the spot-spectra have been carefully examined, and more than 200 lines between B and D are found to be affected. Wolf's Comet was observed during the months of October, November, and December, and fourteen positions have

been completely reduced. *Jupiter's* satellites, occultations of stars by the Moon, the lunar eclipse, and the watch for meteors, have all received our attention.

The Sun-spot drawings of 1883 have all been measured, and those of 1884 are now in hand.

In order to facilitate work with the star spectroscope, a new finder, $3\frac{3}{4}$-inch aperture, has been attached to the Equatorial. This is supplied with illuminating apparatus, and admits of very delicate adjustment.

Mr. Barclay's Observatory, Leyton, Essex.

Vol. v. of *Leyton Astronomical Observations* is in preparation. It is intended that this volume shall contain the results of observations up to the end of the year 1884.

The work includes, generally, observations of double stars, phenomena of *Saturn's* and *Jupiter's* satellites, comets, and occultations of stars by the Moon.

The instruments remain as in former years, but at present Messrs. Beck are making a "Langley" solar eye-piece for the Observatory. This eye-piece is a polarising one.

Mr. Common's Observatory, Ealing.

During the past year a small number of celestial photographs have been taken, including two of the Dumb-bell nebula, and a number of experiments have been made in stellar photography.

The 3-foot Reflector has passed into the hands of Mr. Crossley, of Halifax, at whose Observatory it is now erected. It is intended to replace this instrument with one of 5-foot aperture, made expressly for photography, with a mounting having for the polar axis a hollow iron cylinder floating in water, so as to reduce the friction and vibration of a merely mechanical mounting.

The disk of glass for the large mirror was obtained in 1883, and seems to be all that can be wished for.

The Earl of Crawford's Observatory, Dun Echt.

Some interesting observations were made in the early part o the year of the relatively bright spectrum of Comet Pons-Brooks the returned comet of 1812, which showed four bright bands. The principal bright lines and the great bright band in each of the three Wolf-Rayet stars D.M. $+35°$, 4001, $+35°$, 4013, and D.M. $+36°$, 3956, were also measured on several evenings. The observations

were made with the 12-inch Browning Reflector, some alterations of the eye-end of the 15-inch being in progress. These stars were specially examined in connection with the publication in *Copernicus*, Nos. 35 and 36, of the full report of Dr. Copeland's astronomical experiments in the Andes, in the course of which he detected five objects of this comparatively rare class, besides showing that it probably has its most brilliant representative in γ *Argûs*, which star doubtless offers the most magnificent stellar spectrum permanently visible in the heavens. In the autumn a considerable part of the northern heavens was repeatedly swept with a 6-inch telescope and a prism in front of the object-glass. Four hitherto unnoticed minute planetary nebulæ and one star of the above-mentioned semi-gaseous type were found in this way, as was also Comet Wolf, in advance of the receipt of the news of its discovery in Germany. (*Monthly Notices*, vol. xlv. pp. 90, 91.)

Both phases of the occultation of *Venus* on February 29, and a number of occultations of small stars during the eclipse of the Moon on October 4, were recorded with two telescopes. Late in the year considerable attention was paid to *Saturn* and its spectrum; particulars of these observations, including measures, will be shortly published. The construction of a large spectroscope by Messrs. T. Cooke & Sons, of somewhat special design, is fast approaching completion. Great difficulty has been experienced in obtaining suitable glass for the prisms. Some progress has been made in the examination of parts of the Sun's spectrum with the Rowland grating described in the last report. Ten circulars, all referring to comets, have been issued in the course of the year.

After a long delay the printing of vol. iii. of the Observatory publications has been resumed; it is expected that it will be finished in a few weeks. The Saturday time-gun and daily weather observations have been continued as usual.

Mr. Edward Crossley's Observatory, Bermerside, Halifax.

The observations made at this Observatory during the year 1884 were generally similar to those of previous years. Of the phenomena of *Jupiter's* satellites, 66 were observed, 34 of the conjunctions, &c., of the inner satellites of *Saturn*, and 15 occultations of stars by the Moon. These have been communicated to the Society.

The wedge photometer was ready for use early in the year; and on suitable nights it has often been used, and some hundreds of measures, chiefly for the determination of constants and scale, have been made. Many naked-eye observations have also been made of ten selected variable stars.

Mr. A. A. Common's 3-foot Reflector has been purchased, and

mounted in the Bermerside grounds. A suitable dome will soon be placed over it, and with the return of good weather we hope to begin some useful work with this fine instrument.

The Earl of Rosse's Observatory, Birr Castle.

During the year 1884 astronomical observations were made on fifty-two nights.

Twenty-one drawings of *Jupiter* were obtained with the 3-foot Reflector, also fourteen of *Mars*. Thirteen of the latter are in course of publication in the *Transactions of the Royal Dublin Society*.

Measurements of lunar radiant heat were made with the 3-foot Reflector, principally in connection with the eclipse of October 4. A short preliminary account of them appeared in *Nature*, of October 16, and the complete account is now nearly ready for publication. An exceptionally favourable night made this work more satisfactory than could have been expected.

The 6-foot Reflector was employed on nebulæ during the year, and sketches made.

A short note on the polishing of specula and one on a new electric control for an Equatorial clock were read before the British Association at Montreal.

The meteorological observations were continued as usual.

Colonel Tomline's Observatory, Orwell Park, Ipswich.

The past year has not been favourable for the frequent observation of comets, of which four have received more or less attention during the interval under review. The series of observations of Pons-Brooks' Comet was continued until January 28, seven observations being obtained before it passed to the southward. Repeated attempts were made to observe Barnard's Comet, but only once successfully. It was then found to be so faint, and its position so unfavourable for observation in this latitude, that it was evidently advisable to leave the determination of its orbit to more southern observatories. Observations of Wolf's Comet were commenced on September 25, and are still being continued. Unfavourable weather during the later months of the year has rendered the series a shorter one than was hoped for. Thirteen observations fall within the year. Encke's Comet was looked for unsuccessfully on December 15, since which time no favourable opportunity of repeating the attempt has occurred.

The publication of the results of previous work has been persevered in, and will be found in the columns of the *Astronomische Nachrichten*. Observations of Comets III. 1882, and I.

1883 were published on May 13 in No. 2,592, and of Comet I. 1884 on October 21 in No. 2,623 of that journal.

Cloudy weather prevented the observation of the occultations of small stars during the total eclipse of the Moon on October 4 as proposed by Dr. Döllen, for which preparations had been made.

Lieutenant-Colonel Tupman's Observatory, Harrow.

This Observatory has been built and equipped during the past year. Its situation, taken from the 6-inch Ordnance Survey Map, is in latitude 51° 35′ 15″, longitude $0^h\ 1^m\ 20^s{\cdot}0$ west of Greenwich. The building, 45 feet by 20, is of wood, upon a brick and concrete foundation. The roofs over the telescopes run off upon rails, so that these instruments are used in the open air. The shutter-openings of the Meridian Circle are 2-feet wide, and afford a clear meridian from the northern horizon to N.P.D. 122°. There is a photographic developing-room and a chronograph-room.

The Meridian Circle, by Messrs. Troughton & Simms, has a telescope of $3\frac{3}{4}$ inches clear aperture and 47 inches focal length. The arrangement of the eye-piece micrometers is the same as that at the Royal Observatory, Greenwich, the P.D. micrometer having the same self-recording drums, and the bright-wire illumination is effected by a similar arrangement of internal prisms. The circle is 24 inches in diameter and is read by four microscope micrometers of high power, supported by a massive bronze ring. Their fields are illuminated by means of systems of prisms from a single lamp, with large condensers placed on the prolongation of the axis of the instrument. The instrument can be reversed for observations of Right Ascension, or of collimators, and is provided with a reversing apparatus running on rails between the stone piers.* The collimators, of $1\frac{1}{2}$ inch aperture and 19 inches focal length (doubtless much too small), both provided with micrometers, are mounted in a novel manner on iron pillars, which stand so as to leave the meridian clear for reflection observations, the collimating telescopes moving on hinges on the tops of the pillars. This arrangement seems to possess all requisite stability.

The transit clock, by Molyneux, with steel pendulum rod and mercurial compensation, has been improved by Messrs. E. Dent & Co., and fitted with contact springs and seconds-contact wheel. It is mounted in the dwelling-house, some 50 yards distant from the Observatory. A three-current relay, by Messrs. E. Dent & Co., is worked by the clock circuit.

The chronograph, made by Mr. C. Baker, of Holborn, is a make-circuit Morse recorder, with paper fillet and two pens, which make the records in ink.

* The telescope, transit-clock, and stone piers originally formed part of the equipment of Professor Pritchard's Observatory at Clapham.

There are two Equatorial telescopes. A 4½-inch Refractor, by Messrs. T. Cooke & Sons, standing on an iron pillar with clockwork of their well-known form. A fixed position circle was added by Messrs. Troughton & Simms. This instrument was employed for the observations of the transits of *Venus* in 1874 at Honolulu, in 1882 in New Zealand. It is provided with filar, double-image, crossed bar and ring micrometers, by Messrs. Troughton & Simms. The other telescope is a Newtonian silver-on-glass Reflector of 18½ inches aperture, equatorially mounted and driven by clockwork by Mr. G. Calver, of Chelmsford.

The masonry supporting all the instruments has been sunk 8 to 10 feet into the London clay, and the whole included in a layer of concrete about a foot thick, covering the ground over a space 60 feet by 20.

The 4½-inch Refractor has been chiefly employed on a long series of observations of Wolf's Comet, for place, commencing September 24.

Royal Observatory, Cape of Good Hope.

The present report includes the period 1884 January 1 to December 31. During the year meridian observations have been carried on in accordance with the programme announced in the last report—viz. all stars to 4th magnitude inclusive in the Southern Hemisphere, a selected list of circumpolar stars, all stars of the *Nautical Almanac*, and of the Berlin, Paris, and American Ephemerides to N.P.D. 45°, together with observations of the Sun, *Mercury*, and *Venus*. In addition a large number of comet comparison stars, and stars used for geodetic and other purposes, have been added to the observing list, which will further include stars used in connection with the theodolite observations for Fundamental Declinations.

The following tables show the amount of work accomplished :—

Number of Determinations of	Collimation		48
„	„	Level	423
„	„	Nadir	447
„	„	Runs	600

Observations of Stars.

In R.A.			In N.P.D.		
Direct.	Reflex.	Total.	Direct.	Reflex.	Total.
4011	1627	5638	3638	1631	5269

	Direct.	Reflex.	Total No. of Days.
Observations of the Sun { 2 Limbs each in R.A. / 2 Limbs in N.P.D. }	70	69	139
Mercury	47	12	59
Venus	69	34	103

During the winter months, observations were made systematically by the same observer in the evening and early morning, so that the same circumpolar stars were observed at both culminations, thus affording fundamental determinations of azimuth. The observations in the second watch of the night were carried on by a second observer. On the following night the duties of the two observers were interchanged. In this way fundamental determinations of the places of all stars of the circumpolar list were obtained.

A re-examination of the micrometer screws of the Transit Circle, instituted in September, shows, that in a period of less than five years (the new screws were applied in March 1880), an amount of wear has taken place which, if not determined and allowed for, would seriously diminish the accuracy of the resulting N.P.D.s, and systematically affect the determination of latitude. The errors of these screws were carefully determined in March 1880, and found to be quite insensible.

The results of the recent investigation show that the different screws have worn very unequally in amount, although the general law of wear is nearly the same for all.

The errors of the Declination micrometer screw have also been rigorously investigated.

For the purpose of determining Fundamental Declinations, the great Indian theodolite has been remodelled in many points by Messrs. Troughton & Simms, under the supervision of H.M.'s Astronomer. Efficient means have been provided for determining the errors of the pivots, and new methods arranged for determining the instantaneous level of the horizontal axis. A new eye-piece micrometer has been contrived; two perfectly symmetrical cones, permitting easy interchange of object-glass and eye-end, have been substituted for the former telescope tube; and there is new central illumination of the field. New object-glasses have been provided for the microscopes of the Horizontal Circle, giving double the magnifying power of the old microscopes, and the illumination of the part of the Circle under observation is effected by small incandescent electric lamps (one for each of the five microscopes), the light of each being reflected to the Circle from a dull-white surface. The accuracy of the Circle readings is now fully three times greater than before. Means have also been arranged for a complete determination of the errors of graduation of the Circle.

An Observatory for the great theodolite has been constructed, with a suitable dome, and which will permit easy equalisation of the external and internal temperatures.

The following observations of comets have been made with the 7-inch Equatorial and Repsold wire micrometer :—

Comet	Pons-Brooks	on 43	nights	between Jan. 16	and Apr. 29
„	Barnard	31	„	July 24	Oct. 20
„	Wolf	15	„	Oct. 20	Dec. 15

The observations of Barnard's Comet have been communicated to the *Monthly Notices* and *Astronomische Nachrichten*; those of Comet Pons-Brooks will be communicated so soon as the meridian observations of all the comparison stars have been reduced—a work now in progress—the observations having been made in the early mornings before sunrise. Observations of Comet Wolf are still in progress.

Of the occultations, predicted by the *Nautical Almanac* Office for this Observatory, 22 have been observed during the year.

During the total eclipse of the Moon on October 4, the disappearance or reappearance of seven stars of Döllen's list were observed (three of them by two observers), but the night was a very unfavourable one. The results have been communicated to M. Struve.

During leave of absence in England, H.M.'s Astronomer passed through the press the following works:—

1. "Heliometer Determinations of Stellar Parallax." By Gill and Elkin. (*Mem.* R.A.S.)
2. "The Cape Catalogue of 4,810 Stars for the Equinox, 1850."
3. "Results of Meridian Observations, 1879, 1880, and 1881."
4. "Extra Meridian Observations, 1881, 1882, and 1883."
5. "An Account of the Telegraphic Longitude Operations, connecting Aden and the Cape."

Of these Nos. 1 and 2 have been circulated amongst astronomers; the issue of Nos. 3, 4, and 5 is delayed for the sake of some additions.

The printing of the results of 512 occultations of stars by the Moon has been delayed for the sake of including the results of some observations of the occulted stars received since the work was originally prepared for press.

Advantage was taken by H.M.'s Astronomer of his visit to England to represent the necessity for a new and more powerful Heliometer, to enable him to prosecute his further proposed researches on stellar parallax. The proposal was favourably considered by the Lords Commissioners of the Admiralty, and, on their recommendation, the necessary credit was sanctioned by H.M.'s Treasury. A contract has been entered into with Messrs. Repsold, of Hamburg, for the construction of a heliometer of 7 inches aperture, to be completed by February 15, 1887. The construction of the Observatory (of iron, sheltered by open wooden louvre-work), and of a dome (iron frame, covered by papier-mâché), has been undertaken by Mr. Grubb, of Dublin; and plans for the foundation of this Observatory (including a fire-proof record-room) have been prepared in the office of the Admiralty Director of Works.

The geodetic survey of South Africa makes considerable

progress. In Natal the work in charge of Captain Morris, R.E., has been carried on with remarkable energy and skill. The base-line, measured in 1883, near the centre of Natal, has been extended to the first great side (Zwarlkop-Gilboa), in the centre of Natal, and thence by chains of large triangles southwards to Umtamvuna, in the south of Natal, and westwards to Kokstad, in the eastern part of Griqualand East. Astronomical determinations of latitude and azimuth have been made at Zwarlkop and Umtamvuna, and the longitude of Kokstad has been connected with that of this Observatory by telegraphic operations on six nights. Captain Morris is now pushing the triangulation northwards, and expects to complete the principal triangulation of Natal in August of the present year. This will afford the first geodetic result of the new survey—viz. an arc of about $3\frac{1}{2}^{\circ}$ of latitude, extending from north to south of Natal.

The Volksraad of the Transvaal Republic has voted a sum of 10,000*l.* for commencement of a principal triangulation of the State. H.M.'s Astronomer is in correspondence with Mr. G. R. van Weilligh, Surveyor-General of the Transvaal, and it is hoped that the result will be a friendly co-operation in the general scheme for the geodetic survey of South Africa, and the extension of an arc of meridian from the Natal arc northwards to the Limpopo.

A considerable supply of tidal records is now available; their measurement and discussion are matters which must soon be considered.

The system of time signals remains unchanged.

The meteorological observations, made in the year 1883 at this Observatory, together with those taken in different parts of the Colony, have been printed in the Reports of the Cape Meteorological Commission.

Hong Kong Observatory.

The activity of this Observatory commenced on January 1 with tri-diurnal meteorological observations, monthly absolute magnetic observations, and the issue of daily and monthly weather reports, the former based on telegraphic information received from the Treaty Ports along the China coast and from Luzon. Later on, information was received also from Japan, Wladiwostock, and Tonquin, and full reports and forecasts concerning disturbances were issued daily during the stormy season, and a number of instruments were verified for the observers. The building was finished and all the self-recording meteorological instruments were at work by April 1; and their indications have been tabulated up to date. The transit instrument was erected in April, and meridian marks were subsequently fixed. The instrument was carefully examined, and the observations were

used for rating clocks and chronometers. The large time-ball will be automatically dropped by the mean time clock from January 1, 1885.

The six-inch Lee Equatorial and Sir W. Thomson's automatic tide-gauge, which arrived in the autumn, have not yet been mounted.

Several meteorological papers besides the regular reports have been published in the course of the year, and some progress has been made in the reduction of certain unpublished double-star observations.

Notes on some Points connected with the Progress of Astronomy during the past Year.

Discovery of Minor Planets.

The following nine minor planets were discovered in the year 1884:—

No.	Name of Planet.	Date of Discovery. 1884.	Discoverer.	Place of Discovery.
236	Honoria	Apr. 26	Palisa	Vienna
237	Cælestina	June 27	Palisa	Vienna
238	Hypatia	July 1	Knorre	Berlin
239	Adrastea	Aug. 18	Palisa	Vienna
240	Vanadis	27	Borrelly	Marseilles
241	Germania	Sept. 12	Luther	Düsseldorf
242	Kriemhild	22	Palisa	Vienna
243	Ida	29	„	„
244		Oct. 14	„	„

Up to the present time no fewer than forty-six of these bodies have been discovered by Herr Palisa. Professor C. H. F. Peters has discovered forty-two.

Professor Luther has communicated to the *Observatory* (vol. vii. p. 180) a list of twenty-eight minor planets which have been observed during only one apparition. They are as follows:—

99 Dike	183 Istria	222 Lucia
132 Æthra	188 Menippe	223 Rosa
145 Adeona	193 Ambrosia	225 Henrietta
149 Medusa	197 Arete	228 Agathe
155 Scylla	206 Hersilia	232 Russia
156 Xantippe	208 Lacrimosa	213 Asterope
157 Dejaneira	210 Isabella	234 Barbara
163 Erigone	217 Eudora	235 Carolina
175 Andromache	220 Stephania	236 Honoria
177 Irma		

Of these Hersilia and Isabella have recently been re-observed. The supposed new minor planet, No. 245, the discovery of which was announced by Herr Palisa, on October 27, has been found to be identical with Lacrimosa.

The Comets of 1884.

Five comets have been under observation during the year 1884; brief notes of which are given in the following paragraphs:—

I. *Comet* 1883, II.—This is the comet whose discovery was mentioned in the last Annual Report, and of which it was anticipated that observations would not be possible in these latitudes. It was discovered on January 7 by Mr. David Ross, of Elsternwick, near Melbourne, in 41° South Declination, and gradually diminishing in brilliancy, was last seen on February 4. The elements, computed from the few observations that were possible, show that the comet passed its perihelion on December 25, 1883, so that it should appear in the catalogue of comets for that year. These elements also show that the path of the comet, prior to its discovery, was such that it should have been picked up in this hemisphere. Further, it is seen from this orbit that this comet could not be identical with a bright comet seen in Tasmania, shortly before sunrise on the mornings of December 25 and 27. Unfortunately no accurate observations of this comet were attempted; but the roughly approximate positions point to a northerly motion, which would have soon made the comet visible in Europe.

II. *The Pons-Brooks Comet.*—It is scarcely necessary to add to the notice given last year of this interesting comet of long period. The inconstant form of the nucleus there referred to has since been confirmed by many observers. These rapid and apparently lawless changes, taken in conjunction with the similar phenomena exhibited by the brilliant comet of 1882, very strongly mark the long recognised difficulty of selecting, during a long series of observations, a point which uniformly corresponds with the centre of gravity. The comet is reported to have been last seen on June 2, in New Zealand, but the last accurate observations appear to have been made at Cordoba on May 26, 122 days after perihelion passage. The first observation was made 144 days before perihelion, so that a longer period of observation might have been anticipated, the more so as the theoretical brilliancy at the end of May was $2\frac{1}{2}$ times that at the date of its discovery. Dr. Morrison has obtained elements from some selected positions, which, however, do not embrace the entire period of observation. These elements, in point of accuracy, possess scarcely any advantage over the earlier deduced orbit of MM. Schulhof and Bossert, the close accordance of whose ephemeris with the actually observed path, is acknowledged by Dr. Gould.

III. *Comet* 1884, II.—A comet first seen by Mr. E. Barnard, of Nashville, on the night of July 16, while sweeping in the south-west; but owing to the slow motion in declination and the configuration with neighbouring stars, its cometary character was not detected till the 19th. It differed but little in appearance from the ordinary telescopic comet, and during the whole time of its visibility, up to the latter half of November, it remained an inconspicuous object. The alteration in brightness, as in other comets recently observed, was neither uniform nor consistent with the law of reflected light. The parabolic elements first computed showed some resemblance to those of De Vico's comet of 1844, a comet which, notwithstanding its undoubted elliptical orbit, has not been seen since. This similarity is of the more importance, since later observations, discussed by Dr. Berberich and others, have shown that this comet is moving in an ellipse of short period; but it is scarcely possible that it is identical with De Vico's lost comet of 1844, since the period of forty years does not contain an approximately exact number of revolutions. The period, however, is still very uncertain, Mr. Finlay having given it as 5·6615 years (which would nearly coincide with seven complete periods), while Professor Frisby has given one half a year less. A definite discussion is necessary since the comet can approach the orbits of both *Jupiter* and *Mars*. The closest approach to the latter planet occurs in heliocentric longitude 343° 25′, when the distance is only 0·008, that of the Earth's mean distance from the Sun. Both objects had this longitude in April 1868, when the perturbation was probably considerable.

IV. *Comet* 1884, III.—Discovered by H. Max Wolf, of Heidelberg, on September 17 in the constellation *Cygnus*, but from want of instrumental means, the position of the comet was not obtained till September 20. Dr. Copeland reports that the comet was independently discovered by him at Dunecht, by means of the spectroscope. On September 24 Lieut.-Col. Tupman described the object as a rather bright telescopic comet, showing a stellar nucleus 3″ in diameter, with a faint and diffused coma 2′ in extent. Like the preceding comet, this also belongs to the catalogue of elliptic comets of short period. According to Dr. Krueger, its period is about 2,460 days, but the most interesting fact in connection with the comet is the close approach it must have made to *Jupiter* in May 1875. By direct calculation from the elements, on May 28, 1875, the distance between the comet and planet was only 0·09, and a much closer approach is possible. An attempt has been made by Dr. Lehmann-Filke (perhaps prematurely, considering the uncertainty of the elements, and the neglect of perturbations in the interval) to determine the path of the comet both while in the neighbourhood of *Jupiter* and previously. Accepting his results as approximately correct, the orbit before the perijove differed very materially from that in which the comet now moves, the

eccentricity being only one-half what it now is, while the period was one-third longer. Hence, the perihelion distance is much diminished (from 3·327 to 1·570), which would satisfactorily account for the comet not having been seen at earlier returns. In 1878 the circumstances of the return were unfavourable to observation.

V. *Encke's Comet.*—Re-observed by Dr. Tempel, at Arcetri, on December 13, by means of an ephemeris supplied by Dr. Backlund of Pulkowa. The object was of extreme faintness, and the observation was earlier than might have been anticipated from the circumstances of the somewhat similarly situated return in 1852. The correction to the ephemeris is very small.

In addition to these comets that have been observed, it should be mentioned that Brorsen's comet passed its perihelion in the middle of September, but, it is believed, escaped observation. Unfortunately, no accurate ephemeris was published to assist the re-discovery, and the circumstances for its re-observation were not of the most favourable character, rising as it did about two hours before the Sun in August.

A comet discovered by Tuttle in 1858, but observed only eight times, has recently been the subject of a discussion by M. Schulhof, who has shown that it is another of short period. The mean motion cannot be accurately determined, but corresponds probably to a period of about six and a half years, in which case a return might have been expected in 1884. Sweeping ephemerides have been published, and while searching for it, M. Spitaler observed on May 26 a faint nebula, lying nearly on the path of the comet which has not been seen since. Whether this observation is connected with the missing comet, M. Schulhof considers doubtful, since the comet in that position should have had considerable brilliancy.

W. E. P.

Professor Newcomb's Development of the Perturbative Function.

In the third volume of "Astronomical Papers, prepared for the use of the *American Ephemeris* and *Nautical Almanac*," Professor Newcomb has given an elaborate paper on the Development of the Perturbative Function. Both the method employed, and the mode in which the results are exhibited, present some interesting peculiarities. The analytical developments are expressed in terms of multiples of the eccentric anomalies of the two planets concerned, instead of in terms of multiples of the mean anomalies, which have been more usually employed. The advantage of this is that the co-ordinates of the planets can be far more simply expressed in terms of the eccentric than in terms of the mean anomalies, and that the convergence of the series obtained is much more rapid. When the development in multiples of the eccentric anomalies has been

made, the transformation to mean anomalies is very readily made numerically, by means of Bessel's functions, the application of which for this purpose is fully explained in the paper.

In order to determine the planetary inequalities, it is required to have the development, not only of the disturbing function itself, but likewise that of its derivatives, taken either with respect to the elements, or with respect to the co-ordinates of the two planets. The disadvantage of employing the former derivatives is, that the number of the elements is twice that of the co-ordinates; and, therefore, especially in the cases where it is necessary to take into account the derivatives of the second or higher orders, a much larger number of operations is required to be performed. Besides this, the perturbations of the elements are usually much greater than those of the co-ordinates themselves.

In the present method, the derivatives of any orders, with respect to the co-ordinates, are readily derived from the development of the disturbing function itself. It is, however, necessary to transform the expressions for each derivative from eccentric to mean anomaly separately. It should be remarked that in this paper the disturbing function R is considered as a function of the *logarithms* of the radii vectores of the planets instead of the radii vectores themselves, and that the derivatives are taken with respect to these logarithms accordingly.

Professor Newcomb thinks it probable that in cases where it is necessary to go beyond the sixth power of the eccentricities, or the mutual inclination of the two orbits, a method given originally by Cauchy, and more fully developed by Hansen, will be found more convenient than the present one; and, therefore, the sixth order has been adopted as the limit of the analytical development, although the fundamental formulæ are carried to terms of the seventh order.

At the conclusion of the paper are given tables and very full and clear directions for the practical application of the method.

Professor Newcomb on the Motion of the Seventh Satellite of Saturn.

The same volume of "Astronomical Papers" contains a remarkable paper by Professor Newcomb, entitled "On the Motion of *Hyperion*, a New Case in Celestial Mechanics."

In several papers, published during the past five years, the latest of which is found in the *Monthly Notices* for May 1884, p. 361, Professor Hall has shown, from his own and other observations of *Hyperion*, a remarkable retrograde motion in the perisaturnium of that satellite. He finds that the period of revolution of the perisaturnium is about eighteen years.

At first sight this result appears to be inconsistent with the theory of gravitation. The satellite *Titan* being much the largest and much the nearest to *Hyperion* of all the satellites of *Saturn*, is that by which the motion of *Hyperion* is the most disturbed. But the mean motion of the perisaturnium of this satellite, caused by the action of *Titan*, which is given by the ordinary theory of secular variations, is readily shown to be a direct motion.

In the present paper, Professor Newcomb shows that the difference between this motion, and the retrograde motion given by observation, is caused by a near approach to commensurability in the mean motions of the two satellites.

In fact, four times the mean motion of *Hyperion* is nearly equal to three times that of *Titan*. Now, if l, l' denote the mean longitudes of the two satellites at any time, and ϖ' the longitude of the perisaturnium of *Hyperion*, there will be a term in the motion of this perisaturnium proportional to

$$\cos(4l' - 3l - \varpi'),$$

and multiplied by a constant coefficient, which is much larger than those of the terms which give the ordinary secular variation of the perisaturnium. In consequence of the above-mentioned relation between the mean motions, the quantity $4l' - 3l$ varies very slowly, and diminishes as the time increases. From this it is not difficult to show that the mean rate of variation of ϖ' is the same as the rate of variation of $4l' - 3l$, so that the angle

$$4l' - 3l - \varpi'.$$

oscillates about a mean value, which is found to be 180°, and the motion of ϖ' is retrograde. Hence it follows that *Hyperion* and *Titan* come into conjunction with each other only at or near the apo-saturnium of the former satellite. The result thus obtained is fully confirmed by the observations.

The complete investigation of the law of variation of the above-mentioned angle

$$4l' - 3l - \varpi',$$

is very difficult, and Professor Newcomb only attempts to obtain an approximate solution, from which he deduces that the mass of *Titan* is nearly equal to $\frac{1}{12500}$ of the mass of *Saturn*, and that the greatest amount of the principal inequality in the motion of the perisaturnium of *Hyperion* is about 10°, and also that the difference between the angle $4l' - 3l - \varpi'$ and 180° varies between the limits 18° and −18° nearly.

Professor Safford's Investigation of Corrections to Greenwich Planetary Observations 1762–1830.

Previous to the commencement of accurate observations by Bessel and Struve, the observations made at Greenwich by Bradley, Maskelyne, and Pond, supply almost the only valuable data at the command of astronomers for fixing the positions of the planets between 1750 and 1820. So far as Bradley's observations are concerned, the work of Dr. Auwers may be expected to supply all that is required. In order to utilise the long series of observations made by Bradley's successors, it is now necessary that the work of Maskelyne and Pond should be similarly reduced. For this purpose Professor T. H. Safford has prepared the fundamental formula and tables for the reduction of the planetary observations to the system of Right Ascensions and Declinations adopted in the star catalogues of the *American Ephemeris*, the Declinations being reduced to Boss's system. This work forms one of the important series of astronomical papers prepared for the use of the *American Ephemeris*.

It commences with some brief historical account of the nature of the instruments, and their corrections, used at Greenwich by Bradley, Bliss, Maskelyne, and Pond. The methods of reduction are fully explained. With regard to Bliss's observations, it has been possible to find the instrumental correction of the transit at the Pole, and so to find the probable deviation of the meridian mark. But for the Declinations nothing was attempted. In reducing Maskelyne's and Pond's Right Ascensions the method of Auwers is followed as given in his paper on the Variable Proper Motions of *Sirius* and *Procyon*.

In reducing Maskelyne's Declinations, Olufsen's paper in *Astronomische Nachrichten*, vol. ix., is followed with modifications, such as employing the Pulkowa refractions instead of Bessel's, using the mean declination of Professor Newcomb's catalogue of 1,098 Standard Stars, and in the reduction from mean to apparent place, employing Peters' nutation and Struve's aberration.

The study Professor Safford has made into these observations confirms his view derived from Bessel, that Maskelyne was a good observer in detail, but very negligent in the handling of his instrument. He seems to have been methodical without understanding the importance, which Bradley well knew, of keeping a close watch on the adjustments.

In discussing Pond's Declinations, Professor Safford remarks upon the quadrant then in use at Greenwich, which he infers was a very troublesome instrument to use, and was frequently employed by quite unskilled persons. The plumb-line adjustment of the instrument, he thinks, may have been frequently neglected as too troublesome, or frequently attempted with a disastrous result.

In correcting Pond's Declinations observed with the Trough-

ton Circle alone, a very simple process was sufficient. The slight flexure found by Olufsen in his re-reduction of Pond's observations made with this instrument in 1822, and the fact that the Declinations so determined agree very perfectly with Boss, render it necessary only to correct Airy's index errors for this circle by the reduction from Bessel's Declinations to Boss's.

Tables are appended to the paper, giving differences of mean Right Ascension between Newcomb and Le Verrier of Maskelyne's 36 principal stars for the epochs 1760, 1800, 1840; corrections to the *Tabulæ Regiomontanæ*; instrumental corrections for the years 1762 to 1830 inclusive, chiefly for those times only in that period when planets were observed; corrections to the stars' declination necessary to reduce to Boss; mean declinations of 8 stars in *Gemini* and β and γ *Draconis*, for every 10 years from 1760 to 1810; empirical corrections for the quadrant for the fundamental stars south of α *Geminorum* inclusive, from 1767 to 1787; observations of fundamental stars, 1765 to 1812, corrected approximately for errors of the quadrant; and concluded constants for correcting the quadrant, compared with Olufsen's constants.

The Cordoba Zone-Catalogue.

The private expedition to South America, originally planned by Dr. Gould, had for its object the completion of the general revision of the whole heavens by zone observations similar to those which had been carried out, in the northern hemisphere, by Bessel and Argelander. These extended from 80° of North to 30° of South Declination, and it was known that similar observations around the South Pole had been made by Gilliss while at Santiago de Chile in 1851 and 1852, although these remain even now unpublished. Dr. Gould's original design was to extend his scrutiny of the southern heavens from 28° to 70° of South Declination; but at the strongly expressed desire of Argelander, the northern limit of the Cordoba zones was placed at 23°, and, despairing of an early publication of the zones near the South Pole, the southern limit was transferred to 80° instead of 70° South Declination. This private expedition was, before being carried into effect, adopted by the Argentine nation and became the germ of its National Observatory; and thus it is that this extensive and valuable zone-catalogue, honourable alike to Dr. Gould and to the Argentine nation, appears as a publication of the Argentine National Observatory. In this catalogue there are printed 105,240 separate observations reduced to the epoch 1875·0, giving the positions of 73,160 different stars; so that the mean number of observations for each star is 1·44. The stars are arranged in order of R.A. The magnitudes are also given, the adopted scale being, as

nearly as possible, that of the *Uranometria Argentina*, which does not differ much from Argelander's. The zone observations were commenced in September 1872, and not finally completed (including a revision of all doubtful observations) until June 1883. The observations were made with a Repsold Meridian-Circle, the aperture of the object-glass being 121·9 mm., and its focal length 1·463 metres. The diameter of the graduated circle is 716 mm., and it is read by four microscopes. In the zone observations (in which two persons were simultaneously employed) it has been usual to take the transits of stars over three threads, and to read the circle by one microscope only, the difference between this reading and that of the mean of the four microscopes having been determined every day. The very creditable accordance of the separate observations is shown by a discussion of the results for stars which have been observed more than twice, from which it appears that the average discordance in Right Ascension is $0^s{\cdot}062$ expressed in equatorial time; and the corresponding quantity in Declination is $0''{\cdot}972$. The *Cordoba Zone-Catalogue*, therefore, contains a very complete and accurate survey of the southern heavens, within the limits of declination mentioned above, down to magnitude $9\frac{1}{2}$ (containing also many stars of the 10th magnitude); and although it has cost Dr. Gould some thirteen years of assiduous toil, still it will doubtless be sufficient recompense to him, on his return home, to feel that he has rendered great service to astronomy during his sojourn at Cordoba, not only by the publication of his zone-catalogue, but also by his *Uranometria Argentina* (already published), and by his General Catalogue of Southern Stars, which he intends to bring with him for publication in the northern hemisphere. A. M. W. D.

The Glasgow Catalogue of Stars.

The astronomical history of the Glasgow University Observatory may be said to begin with the acceptance of the directorship in 1859, by Professor Grant. Finding it furnished with a Meridian-Circle, by Ertel & Sons, of Munich, of six French inches aperture, his first idea was to re-observe a certain number of stars, selected from the British Association Catalogue, but he soon enlarged his field of work, and set himself the stupendous task of carefully re-observing some 6,000 telescopic stars, selected from the first volume of Weisse's Bessel, and, therefore, within 15° of the Equator. Although having but one assistant, who, moreover, was frequently changed during the progress of the work, this object was steadily kept in view; and the volume before us, the first separate work issued from the Observatory, is the result of the patience and perseverance with which it was prosecuted.

The volume is prefaced with a short history of the Observa-

tory; then follows the introduction to the Catalogue, describing the principal instrument and methods of observing in all detail necessary for an opinion to be formed of the quality of the work.

As it formed no part of Professor Grant's project to determine absolute Right Ascensions—indeed, he states that in the climate of Glasgow the determination of the Azimuth constant, by upper and lower culminations, to be rarely possible—the Right Ascensions of the clock stars, as given in successive volumes of the *Nautical Almanac*, from 1861 to 1881, have supplied the fundamental Right Ascensions of the Catalogue.

The Greenwich first 7-year Catalogue for 1860 was used for the *Nautical Almanac* places of clock stars from 1871 to 1879, both inclusive; and as the greater part of the observations were made during these nine years, "the Right Ascensions of the Glasgow Catalogue may, therefore, be said to be mainly based upon the equinox of the Greenwich Catalogue for 1860."

To illustrate the annual variation of the instrumental constants, the level, collimation and Azimuth errors are given in full for the year 1866. The daily rate of the transit clock is given for 1867.

The North Polar Distances, which have been derived in an unusual manner, form a feature of the catalogue deserving (and requiring) close attention. The errors of division of the circle were determined in the usual manner for every 5°, and the error for each degree was inferred from an interpolating curve based upon the 5° errors. The observed Nadir point is given for 1861, 1870, and 1879, and the correction for runs of the screws of the microscope micrometers for 1866.

The peculiarity of the method of determining the North Polar Distances are best described in Professor Grant's own words:—

"The collimators which had been mounted in 1842 were found to be unfit for use. A comparison of the North Polar Distances observed during the period 1860–64 with the corresponding places of the Greenwich 7-year Catalogue for 1860, showed very satisfactorily that the systematic errors of the Glasgow observations, whether arising from flexure or any other unrecognised source, must be small. On the other hand, a comparison of the observations made subsequently to 1864 with the Greenwich Catalogue exhibited a pronounced residual difference depending on the zenith distance of the star. I am inclined to attribute this circumstance to a change in the flexure of the telescope tube occasioned by the introduction of the new eyepiece, observations with which were commenced in January 1865. I therefore decided upon determining the final correction to the North Polar Distances of the General Catalogue by means of the North Polar Distances of Stars observed during the period 1860–64. In pursuance of this view I formed a preliminary catalogue of the North Polar Distances of thirty stars based exclusively upon observations made during the period referred to. These results I then employed in the preparation of a definitive or

standard catalogue resting upon a broader basis of observation, a catalogue of the North Polar Distances of 116 stars derived from the observations made at the Glasgow Observatory during the twelve years extending from 1860 to 1871, and including the stars contained in the preliminary catalogue. . . . .

"The next step was to derive from the North Polar Distances of the preliminary catalogue a correction to the North Polar Distances of the larger catalogue of 116 stars. It has been already stated that the thirty stars of the preliminary catalogue were included in the larger catalogue here referred to. A comparison of the corresponding North Polar Distances of the two catalogues arranged in the order of magnitude of North Polar Distance, gave, for the correction applicable to the thirty North Polar Distances of the larger catalogue, the expression—$1''\cdot28 \sin z$, z denoting the zenith distance of the star."

A comparison between the North Polar Distances of the preliminary catalogue and the North Polar Distances of the same stars in the larger catalogue, corrected as above, warranted the application of the same correction to all the other stars of the larger catalogue. Accordingly this was done, and the final North Polar Distances were obtained of the larger catalogue, which was henceforth assumed as the standard catalogue by means of which was determined, in every instance, the final corrections to the observed North Polar Distances of the General Catalogue. The method of obtaining the correction in a given case is explained at length, and both the preliminary and the larger catalogue of North Polar Distances are given, with abundant illustration of the application of this final correction.

The value of the catalogue is greatly enhanced by the publication of the Star Ledger, which indeed forms the bulk of the volume. Means are thus supplied for correcting any catalogue place of the star for equinox or proper motion.

The catalogue not only supplies much more accurate places than those at present available of a large proportion of Bessel's Stars, which observers (and still more calculators) of comets and minor planets will duly appreciate, but the places have that accuracy, certainly in Right Ascension, which fits them for investigations of proper motion. Professor Grant has in fact investigated the proper motions of ninety-seven of his stars which were common to Lalande and Bessel.

The proper motions of Bradley's Stars have not been generally applied to the Glasgow Catalogue places. A comparison between the Glasgow places and the places in the Greenwich 9-year Catalogue for 1872 (the epoch of the Glasgow Catalogue is 1870) of the first fifty stars common to both catalogues shows a very close agreement in Right Ascension, a difference of $0^{s}\cdot1$ being rare. Differences in N.P.D. of $2''$ are not uncommon (six of the fifty ranging between $1''\cdot5$ and $2''\cdot5$); but this, perhaps, is no more than should be expected. A very large number of Schjellerup's Stars are found in the catalogue, the limits of N.P.D. being practically the same.

The catalogue has been discussed by Dr. A. Auwers in *Vierteljahrsschrift der Astr. Gesellsch.*, Jahrg. XIX. Heft 3.

The volume is carefully printed, and in an exceptionally handsome manner, by H.M. Government on the recommendation of the Committee of the Royal Society.*

Dr. Backlund's Investigation of the Motion of Encke's Comet.

Dr. Backlund, of Pulkowa, has published in the *Mémoires de l'Académie Impériale des Sciences de St. Pétersbourg*, tome xxxii., the results of an important investigation on the motion of Encke's Comet during the years 1871–1881, in which he not only removes some doubts which are left unexplained in Von Asten's classical memoir on the subject, but materially advances the theory of the Comet. It will be remembered that the researches of Von Asten, while completely establishing the fact of the acceleration of the mean motion, and confirming the amount previously derived by Encke, nevertheless indicated that the observations, made subsequently to 1865, could be represented by a purely gravitational theory. This apparent discontinuity in the law is shown by Dr. Backlund to have its origin in the employment of erroneous formulæ for the computation of the perturbations of the second order for the period 1865–1868. Owing to the approach of the Comet to *Jupiter* in that revolution, these perturbations are considerable, and the error thus introduced, though not yet definitely determined, amounts approximately to 18″ in the mean anomaly, and to +0″·06 in the mean motion.

In addition to the removal of this perplexing difficulty, Dr. Backlund introduces a greater delicacy into his calculations by substituting a more accurate method of computing the mean anomaly. In Von Asten's calculations the alteration in the mean motion produced by the so-called "resisting medium" is made *per saltum* at the moment the Comet passes through perihelion. Dr. Backlund prefers to apply this correction (as also the consequent increment to the eccentricity) in proportion to the time, and further considers the effect of a periodic term, hitherto neglected, but which is a necessary consequence of the original hypothesis. On the assumption that the acceleration (μ') is 0″·104, this periodic term becomes $-8''\cdot15 \cos 2u$, where $2u$ is an angle depending on the true anomaly, and may vary 40° or 50° in an apparition. This term, therefore, is clearly not negligible, and the small corrections to planetary masses, &c., which have been inferred from the discussion of the motion of this Comet, in which this term has not been considered, are subject to a proportionate degree of uncertainty.

* The following misprints were noticed: No. 168 proper motion in R.A. should be −·018. No. 340 is μ *Piscium* not ω. No. 249 is Piazzi 246.

The final comparison of the theoretical positions with the normal places (17 in number) is made on three assumptions—1, neglecting this periodical term; 2, retaining it; and 3, with the periodic term still retained but the Bessel-Schur mass of *Jupiter* substituted for the value derived by Von Asten from the discussion of the motion of this Comet. The principal results can be best seen from an inspection of the following table:—

	Correction to Daily Motion.	Consequent Corr. to Eccentricity.	Value of Periodic Term.	Prob. Error of Normal Place.
Hypothesis I.	+0″·045982	−1″·61	″	±5″·005
„ II.	+ ·04575	−1·61	−3·54	±4·161
„ III.	+ ·054000	−1·90	−4·20	±2·777

The smallness of the probable error of a normal place in the third hypothesis is remarkable, when all the causes that contribute to augment it are considered; and there can be no doubt that the conclusion of a gradual diminution in the acceleration drawn from an inquiry so rigorously conducted in its methods, and so satisfactory in its results, is entitled to very great weight.

This gradual diminution, although its explanation is not easy to conjecture, is best shown by quoting the various values that have been assigned to it, with their probable errors.

1819–65 ... ... $\mu' = +0''\cdot104418 \pm 0''\cdot0001353$

1865–71 ... ... $\mu' > +0''\cdot06 < +0''\cdot10$

1871–81 ... ... $\mu' = +0''\cdot054000 \pm 0''\cdot0005244$

Dr. Backlund concludes his paper by some theoretical considerations of the law by which the resisting medium might operate. The hypothesis has hitherto been exclusively confined to that case in which the accelerating force is supposed to act directly as the square of the velocity, and inversely as the square of the distance. Dr. Backlund considers the effect on the path of the Comet of a force acting proportionally to any positive power of the velocity and any negative power of the distance, and gives rigorous formulæ for the variations of the mean motion, eccentricity, (ϕ') longitude of the perihelion, and the mean anomaly. The effect on the longitude of the perihelion is shown to consist entirely of periodic terms, and of so small an amount that their detection by observation is impossible; but since Von Asten determined directly from the observations the variation of the eccentricity, a comparison between his result and the theoretical value is possible, and it might have been anticipated that some confirmation of, or alteration in, the law as originally imagined by Encke could be effected. Von Asten's determination of ϕ' is, however, accompanied by a probable error of such an amount

as to prevent any trustworthy deduction in this direction; and the only certain conclusion to be drawn from the comparison is, that there is no ground for preferring Encke's hypothesis to any other which, while preserving the ratio between μ' and ϕ', offers additional computational advantages. W. E. P.

Dembowski's Double Star Measures.

A very valuable addition to observational Astronomy has been made by the publication in two volumes of Baron Dembowski's micrometric measurements of double stars. Those who have had to hunt through scattered numbers of the *Astronomische Nachrichten* for observations will much appreciate this work.

Vol. I. contains a short biographical notice of the author by MM. Otto Struve, and G. V. Schiaparelli, in which they bear testimony to the admirable perseverance of Dembowski, who in the seventeen years from 1862 to 1878 made many thousands of measures of double stars; and when it is remembered that he was then (1862) fifty years of age, it will always be a satisfaction that his merit was recognised by the reward of the medal before his death.

This volume contains six groups of measures, these being (1) a long series of re-measurement of stars taken from Struve's *Mensuræ Micrometricæ*; (2) re-measurement of over 400 stars from Otto Struve's catalogue; (3) a series of measures of stars whose distance is between $32''$ and $120''$; (4) a series of measures of double stars whose duplicity was discovered by Mr. Burnham; (5) a series of measures of double stars discovered by Herschel, I. and II., Dawes, Alvan Clark, Schjellerup, and Dembowski, and finally a set of observations of 26 circumpolar stars. It would have been more convenient if the approximate places in both elements (say to the nearest minute) had been printed on a line with the star's name and Struve's number, instead of being placed in an appendix.

Vol. II. contains an introduction, which is divided into ten chapters, and treats of the telescope, the mode of observation, the value of micrometer revolutions, &c., and the whole of these chapters are worthy of study, showing as they do the care taken by Dembowski in clearing his observations of instrumental errors. Details are then given of his methods for determining the probable errors of single observations, which show that in the closer stars his results agree very well with Struve's, as given in the *Mensuræ Micrometricæ*.

The great attention paid to some of the short period binary stars may be inferred when it is stated that no less than 120 sets of measures were made of η *Cassiopeiæ* between 1862 and 1878; 44 of 36 *Andromedæ*, of ζ *Cancri* 126, and on most occa-

sions the stars were seen divided sufficiently to *estimate* distance, and from 1874 to 1878 *measures* of distance were obtained with a power of 500.

ξ Ursæ Maj. was observed on 134 nights, and measured from a position angle of 99°, through its retrograde motion to an angle of 284°.

γ Virginis, *ξ Boötis*, *η Coronæ* (the distance of which has, in nearly every instance, been *measured*), *ξ Libræ*, *λ Ophiuchi*, *ζ Herculis*, *τ Ophiuchi*, 70 *Ophiuchi*, *δ Cygni*, have all received an extraordinary amount of attention.

An appendix is given showing the correction for refraction to be applied to stars of the Dorpat Catalogue, whose distances exceed 32″.

Dunsink Parallax Researches.

In Part V. of the Dunsink Observations Dr. Ball publishes the second instalment of his researches on stellar parallax. Part III. (1879) contained his observations of forty-two stars which showed that no one of them had a large annual parallax. The present volume contains the observations of no less than 368 objects, not one of which rewarded the indefatigable observer by indicating a parallax large enough to be detected by the methods employed.

The volume also contains "Further Researches on the Annual Parallax of 61 *Cygni*," by differences of declination measured in 1878–79 on thirty-seven nights, with the result—

$$+0''.47 \pm 0''.03.$$

Also special investigations of the parallaxes of *Groombridge* 1618, *Piazzi* III. 242, and 6 *Cygni*, with the following results :—

Groombridge 1618, from observations on 106 nights in 1878–80, annual parallax—

$$+0''.32 \pm 0''.02.$$

Piazzi III. 242, from observations on thirty-one nights in 1879, annual parallax—

$$-0''.04 \pm 0''.07,$$

which indicates that the difference between the parallaxes of the two stars compared is too small to be measured.

6 *Cygni*, from observations on thirty-seven nights in 1880–81, annual parallax—

$$+0''.48 \pm 0''.05.$$

Professor Pickering's Observations with the Meridian Photometer during the Years 1879–82.

This publication, in several points of view, presents remarkable and interesting features. For centuries past the apparent comparative lustre of the stars has engaged the attention of astronomers from Ptolemy downwards, and many of them have left records of the result of their labours given in well-known catalogues. These, however, were but estimations of comparative brightness made with greater or less success by the unaided eye. There have also been a few very valuable, but somewhat spasmodic, attempts made to apply various forms of photometric measures, claiming an exactness belonging to a higher order of scientific merit.* In the volume before us we have the first record of a systematic investigation of "star magnitudes" made with a photometer contrived on unimpeachable principles, and extended to all stars recorded in the catalogue of Argelander's "Uranometria Nova," with the addition of some others, down to the sixth magnitude and above the parallel of 30° South Declination. It is true that this Harvard Catalogue has been anticipated by the publication of a regular series of photometric observations made at Oxford, with a very different but probably equally reliable instrument, but the latter research, so far as at present published, extends only so far as stars ranging between the first and the fourth or fifth magnitudes.

The volume containing these observations consists of 324 closely printed pages, embracing a mass of print which of itself excites the attention of the reader. It is divided into six chapters. The first of these contains a description of the photometer employed. It is an ingenious adaptation of various expedients devised by successive astronomers, from Sir J. Herschel down to the present time, but possessing features of its own, which may fairly establish its claim to be regarded as an original instrument. The general principles of the construction and use of the instrument seem fairly clear. Two similar telescopes, each having an object-glass of about one and a half inch aperture and thirty inches focal length, with a power of fifteen linear, are placed horizontally in juxtaposition. On each of the object-glasses is a rectangular prism, by the motion of which it is mechanically contrived that the images of *Polaris* and of any star in or very near the meridian can be formed in the focus of each telescope, and so viewed in juxtaposition by means of one eye-piece. Before these images are formed, the pencils from the two stars pass through an optical arrangement of double refraction, so arranged that by gradually rotating a Nicol prism the two polarised images may be equalised, and in this way, by means with which physicists

* For the history of these researches, see *Memoirs, Roy. Astr. Soc.*, vol. xlvii. p. 367.

are familiar, it is possible to measure the relative brightness or magnitudes of *Polaris* and the star in question. Two persons are necessary for the observation. The one moves one of the prisms so as to place the image of the meridian star in the field of view, while the observer, properly so called, has the command of *Polaris*, and he also turns the Nicol prism until the two images are equalised. The position of the Nicol is read and recorded by the assistant, whose eye is not before the telescope. The observer then reverses the images of the two stars, right and left, by moving the *Polaris* prism, and then the operation of equalisation is repeated. We do not doubt that this principle of reversing the images was necessary, as it is stated that it was ultimately found to be, in order to secure the precision of the measures, but we are greatly disposed to doubt whether the necessity of this operation does not arise from other contributory causes than those assigned in the volume—viz. from the fact that the human eye may be greatly biased in its estimate of the relative intensity of two lights in juxtaposition, by their mere relative position of right and left. These operations of setting, equalising, reading, reversing, &c., are performed with such rapidity, that we believe the average number of complete observations does not fall below forty per hour. The necessity for these extremely rapid observations appears to arise chiefly from the construction of the instrument, there being, so far as we can gather, no automatic contrivance provided for the motion of the instrument to follow the southern star; the many and serious discordances recorded in the individual measures may, we think, be attributed partly to this rapidity, and, it may be presumed, the accuracy of the resulting mean is affected thereby. Nevertheless we cannot overlook the judgment and ability of Professor Pickering in devising the method before us, and the effect of the discordances of the individual measures may, in some cases at least, possibly be obviated by the number of the observations.

Chapter II. is chiefly occupied in giving a summary of the whole operations, and in discussing the conventional magnitude of *Polaris*, which was found from observations to be practically invariable during the three years occupied by the work, viz. from October 1879 to September 1882.

Chapter III. is occupied by the atmospheric absorption of light emanating from the stars. The coefficient of absorption finally adopted is ·25 of a magnitude on Pogson's scale. This coefficient, though coinciding exactly with that determined at Oxford, is greater than that determined at several places on the Continent of Europe, and seems to imply a somewhat vaporous atmosphere at Harvard. A peculiarity in the method of these observations consists in the fact that they were necessarily made on stars viewed in the same azimuth, viz. due north. This we are disposed to regard as liable to objection, inasmuch as the absorption corrections are for the most part to be made to stars observed in the contrary direction, viz. due south where

the meteorological and topical circumstances may be very different. A very far more serious objection is that the same coefficient is applied on all nights, wherein the meteorological conditions greatly vary, and the coefficient is very seriously affected thereby. Whether or not this difficulty is removed by the multiplication of the observations it is not easy to see, but individual observations must be seriously affected, and of these we think we see decided traces. If in photometrical work the utmost attainable accuracy is not secured, it is difficult to see where it is superior to ordinary estimations by the unaided eye. In many questions it is important to discriminate between the mean and the actual brightness of a star at a particular epoch.

In the fourth chapter are given the results of eye estimations of the brightness of most of the stars photometrically measured. Professor Pickering says that "it is obviously desirable that photometric determinations of the light of stars should be compared with similar results obtained by the direct estimation of relative brightness." Granting this, it seems obviously still more desirable that where the photometric and the direct observations disagree, the cause should be at once searched into, and, if possible, eliminated. For it is impossible to overlook the fact that in a very great many instances there are recorded in the Harvard volume serious differences between the photometric and the direct observations, amounting sometimes to as much as half a magnitude, and occasionally even larger discrepancies are observable. There seems but one conclusion to be drawn from a fact of this nature: either the photometer or the eye is in error; and it is worthy of remark that the individual deviations of the eye estimations are not perceptibly much more discordant than are those of the recorded photometric measures. It seems probable, notwithstanding these and other advances in stellar photometry, that we have not as yet anywhere arrived at a degree of precision which can properly be regarded as final.

In the fifth chapter are given the main results of the entire investigation. It is impossible not to be struck with the immense amount of labour and indefatigable zeal to which every page in this chapter bears witness. It contains the records of the results of an immense undertaking even for the eight or nine observers employed therein during the space of three years. The pages of this chapter are a model of condensation, and afford in a brief space an enormous amount of information of the processes involved in the actual observations, and of the results of many previous observers.

With one or two final remarks we shall conclude our rapid summary of the contents of this remarkable volume. There are given the results of no less than fourteen sets of eye estimations of stellar lustre made by various antecedent astronomers. The resulting magnitudes are said to be reduced to an uniform scale. This we should have regarded as not possible, having regard to scientific accuracy. In estimates made by the unaided eye, an

uniform numerical scale, reaching from the brightest to the faintest star, seems impossible, and beyond all doubt no such scale exists when examined by the aid of photometric results.

The records of a great, difficult, and original work, such as the one before us, containing, as it does, an enormous amount of unavoidable detail, and executed in so brief a time, must contain a few blemishes, more or less; and if we have indicated some instances which appear open to criticism, it is not inconsistent with a hearty participation in the admiration which is deservedly entertained by practical astronomers for this very important addition to the science which this volume undoubtedly extends.

C. P.

Dr. Huggins's Method of Photographing the Solar Corona without an Eclipse.

At the anniversary meeting of the Royal Society the Treasurer, Dr. Evans, made the following statement:—

"In his address last year the President called attention to the discovery by Dr. Huggins of a method of photographing the Solar Corona without an eclipse; and for the purpose of making further experiments in this direction, and for carrying on other physical observations at some place of high elevation and of easy access, a grant of 250*l.* was placed at the disposal of a committee. The place of observation selected by the committee was the Riffel, near Zermatt, in Switzerland, which has an elevation of 8,500 feet, and possesses important advantages both of access and of hotel accommodation. They appointed Mr. C. Ray Woods, who had had experience in photographing the Corona during the eclipse of 1882 in Egypt, and again in Caroline Island in 1883, to take charge of the work under the instructions of Dr. Huggins and Captain Abney.

"Mr. Woods arrived at the Riffel in the beginning of July, when he erected the necessary instruments under a tent of 'Willesdenised' paper, and continued at work there until September 21. Unfortunately, the present year has been exceptionally unfavourable for work on the Corona, in consequence of an unusual want of transparency in the higher regions of the atmosphere. This probably may be owing to the presence there of ice crystals or of small particles of matter of some kind, such as, personally I am tempted to think, might be due to the Krakatoa eruption. Whatever the cause, the sky as seen from the Riffel was far from being so clear as it has been during former years. Mr. Woods observed that the freer the lower air was from cloud and mist, the more distinctly came out a great aureola around the Sun; which he found to have a diameter of about 44°, and to be of a faint red near the outer boundary, and bluish-white within, up to the Sun's limb.

"These unfavourable conditions of the atmosphere have made it impossible for Dr. Huggins to obtain any photographs of the Corona in England. The great advantage at the Riffel of being free from the light scattered from the lower eight thousand feet of air has enabled Mr. Woods, notwithstanding the serious drawback of the persistent aureola, to obtain about one hundred and fifty photographs, of which more than half are sufficiently good to show the general form of the Corona, and a smaller number the stronger details of that part of the Corona which lies within from 8′ to 12′ of the Sun's limb. It would be premature to express any opinion as to the information which may eventually come out from the Riffel plates. They are now being drawn preparatory to a full discussion. In the meantime I may congratulate the Society upon the confirmation of the hope expressed by our President at the last anniversary that 'a new and powerful method of investigation has been placed in the hands of students of Solar Physics.'"

By the aid of a special grant from the Government fund, Dr. Gill is going to take a series of daily photographs of the Solar Corona, as part of the regular work of the Cape Observatory, for the carrying out of which he has engaged Mr. Woods as assistant.

Professor Langley on the Amount of the Atmospheric Absorption.

The results of his various investigations on Solar Radiations have led Professor Langley to a conclusion, as to the amount of the absorption exercised by our atmosphere, most strikingly at variance with the views generally held. He communicated a paper on the subject to the National Academy of Sciences in April 1884, and has since reproduced its substance in an article which appeared in the *American Journal of Science* for September 1884. The point upon which his argument turns is, that up to the present time it has been almost universally assumed in the reduction of observations that the coefficient of transmission is a constant, an assumption involving the further one, that the solar radiations are either perfectly homogeneous, or suffer absorption as if they were. But we now know that they are of an infinite degree of complexity, and that they are affected in very diverse degrees by their passage through our atmosphere.

It is clear, therefore, that the usual exponential formula, $Ap^e=t$, is inexact, and Professor Langley has no difficulty in showing by a simple algebraical treatment of a case in which the radiations are supposed to be of two kinds only, that it is erroneous always in the same direction, since it always makes the coefficient of transmission too large, and always larger and larger as the horizon is approached. The amount of the error is not, however, indicated, and since the value of the coefficient of transmission, as found by a number of observers from many

thousands of observations over a wide range of zenith distances of the Sun has been practically, always the same, it might be urged that it could not be very great. To this objection Professor Langley replies by showing that the error will increase with the difference between the coefficients proper to the various individual radiations, so that "however close the agreement may be between observations on absorption made at quite different altitudes of the heavenly body, we have no right to infer that the error of the final result is not indefinitely great." It is obvious that the error will be very serious if the coefficients for a large number of radiations approach zero; and Professor Langley points out that the presence in the spectrum of strongly marked telluric lines, even in observations made at great elevations above the sea, is evidence of coefficients of transmission for those particular rays, which must be small indeed. He then takes an imaginary instance in which the radiant energy before absorption is supposed to be divided into ten parts, each with its own coefficient of transmission, and he chooses values for these so as to represent as nearly as practicable the observed facts of nature. Reducing by the ordinary method the values observed after one, two, three, and four absorptions, he shows that the values of the atmospheric absorption which would be obtained would be 21, 19, and 18 per cent.; whereas the actual absorption would have been 41 per cent., or more than double the mean of the three separate determinations, although these accorded with each other very fairly.

To obtain a truer view than we have at present of the loss by atmospheric absorption, we are only able to divide the spectrum into a finite number of parts and to sum the results. This Professor Langley has already achieved to a considerable extent by means of his Bolometer, though even with this instrument, as he is careful to note, we are far from dealing with truly homogeneous rays, and we can only regard the error as lessened, not as removed. Professor Langley, by his observations on the summit and at the foot of high mountains, avoided some of the sources of error incident to the ordinary method of observing a high and low Sun, and he recommends the further development of his method when practicable. But he also suggests a third method more generally applicable—viz., the comparison of the heat and light from the sky around the Sun with that from the whole sky apart from the Sun, since it is clear that the whole of the light reflected to us from a pure and uniform sky—on the average he estimates, as much as we receive directly from the Sun—represents so much loss in the direct transmission. Professor Langley concludes by asserting his belief, which seems well supported by the evidence he has adduced, that the mean absorption of light and heat by our atmosphere is, in all probability, *at least double* that at which it is customarily estimated, and that fine dust particles play a more important part in this absorption than has been heretofore supposed.

It should be added that although stellar radiations must suffer loss in the same general proportions as solar, yet, that since our determinations of stellar magnitudes are relative only, these will be but little affected, except in the case of stars of pronounced colour, by the error of the formula usually adopted for atmospheric absorption. E. W. M.

The International Meridian Conference.

On the invitation of the President of the United States a conference of delegates from twenty-seven States met at Washington on October 1, under the presidency of Admiral Rodgers, U.S.N., to fix on a meridian proper to be employed as a common zero of longitude and standard of time-reckoning throughout the world. After a full discussion the following resolutions were adopted :—

I. "That it is the opinion of this Conference that it is desirable to adopt a single prime meridian for all nations, in place of the multiplicity of initial meridians which now exist."

This resolution was adopted unanimously.

II. "That the Conference proposes to the Governments here represented the adoption of the meridian passing through the centre of the transit instrument at the Observatory of Greenwich as the initial meridian for longitude."

This resolution was adopted by the following vote :—
In the affirmative—

Austria-Hungary	Mexico
Chili	Netherlands
Colombia	Paraguay
Costa Rica	Russia
Germany	Salvador
Great Britain	Spain
Guatemala	Sweden
Hawaii	Switzerland
Italy	Turkey
Japan	United States
Liberia	Venezuela

In the negative—
San Domingo.

Abstaining from voting—
Brazil France

Ayes, 22 ; noes, 1 ; abstaining 2.

III. "That from this meridian longitude shall be counted in two directions up to 180 degrees, east longitude being plus and west longitude minus."

This resolution was adopted by the following vote:—
In the affirmative—

Chili	Liberia
Colombia	Mexico
Costa Rica	Paraguay
Great Britain	Russia
Guatemala	Salvador
Hawaii	United States
Japan	Venezuela

In the negative—

Italy	Sweden
Netherlands	Switzerland
Spain	

Abstaining from voting—

Austria-Hungary	Germany
Brazil	San Domingo
France	Turkey

Ayes, 14; noes, 5; abstaining 6.

IV. "That the Conference proposes the adoption of a universal day for all purposes for which it may be found convenient, and which shall not interfere with the use of local or other standard time where desirable."

This resolution was adopted by the following vote:—
In the affirmative—

Austria-Hungary	Mexico
Brazil	Netherlands
Chili	Paraguay
Colombia	Russia
Costa Rica	Salvador
France	Spain
Great Britain	Sweden
Guatemala	Switzerland
Hawaii	Turkey
Italy	United States
Japan	Venezuela
Liberia	

Abstaining from voting—

Germany	San Domingo

Ayes, 23; abstaining, 2.

V. "That this universal day is to be a mean solar day; is to begin for all the world at mean midnight of the initial meridian,

coinciding with the beginning of the civil day and date of that meridian; and is to be counted from zero up to twenty-four hours."

This resolution was adopted by the following vote:—
In the affirmative—

Brazil	Japan
Chili	Liberia
Colombia	Mexico
Costa Rica	Paraguay
Great Britain	Russia
Guatemala	United States
Hawaii	Venezuela

In the negative—

Austria-Hungary	Turkey
Spain	

Abstaining from voting—

France	San Domingo
Germany	Sweden
Italy	Switzerland
Netherlands	

Ayes, 14; noes, 3; abstaining 7.

VI. "That the Conference expresses the hope that as soon as may be practicable the astronomical and nautical days will be arranged everywhere to begin at mean midnight."

This resolution was carried without a division.

VII. "That the Conference expresses the hope that the technical studies designed to regulate and extend the application of the decimal system to the division of angular space and of time shall be resumed, so as to permit the extension of this application to all cases in which it presents real advantages."

This resolution was adopted by the following vote:—
In the affirmative—

Austria-Hungary	Mexico
Brazil	Netherlands
Chili	Paraguay
Colombia	Russia
Costa Rica	San Domingo
France	Spain
Great Britain	Switzerland
Hawaii	Turkey
Italy	United States
Japan	Venezuela
Liberia	

Abstaining from voting—

Germany. Sweden.
Guatemala.

Ayes, 21 ; abstaining, 3.

These resolutions, which were proposed by Mr. Rutherford (one of the delegates of the United States), differ from the recommendations of the meeting of the Geodetic Association at Rome, in October 1883, in two important points: (1) That the practice of reckoning longitude from 0° to 180° east and west of the initial meridian is to be retained, the proposal to count in one direction only from 0° to 360°, which was adopted at Rome, being rejected at Washington. (2) That the universal day should begin at Greenwich mean midnight (coinciding with the civil day) instead of beginning at Greenwich mean noon (coinciding with the astronomical day) as recommended at Rome.

As regards (1), the proposition to count longitude from 0° to 360° eastward, which was adopted without discussion by the Geodetic Association (composed of European astronomers and geodesists), met with strong opposition from the representatives of the various States of North and South America, who considered that the proper direction in which to count longitude was westward, and it became evident that no agreement could be expected as to the direction to be adopted. Under these circumstances it was considered preferable to retain the existing practice of geographers and navigators, and Professor Adams pointed out that there was no difference of principle between the practice of counting in one direction only, or in two opposite directions, considering longitudes measured in one direction as positive and in the other direction as negative. In the former case, however, there would be discontinuity in passing from 360° to 0° at the prime meridian, which passes through densely populated countries, whilst in the latter the discontinuity would occur in passing from $+180°$ to $-180°$, viz. in mid-ocean, where it would cause very little inconvenience, and where ships are now in the habit of making the change of date.

The proposal to reckon universal time from noon of the initial meridian, which was carried by a majority at Rome, was strongly opposed at Washington by the delegates from the United States, Russia, and Great Britain, the feeling expressed being that the transition from local or other standard time in ordinary use to universal time should be as easy as possible, whilst the view of the Committee of the Geodetic Association, which proposed noon as the starting-point, was that local time should not be in any way related to universal time, and that the latter should be used only for the internal service of railways and telegraphs. According to this scheme universal and local time would be kept as distinct as possible, the hours of the former being counted from 0 to 24, starting with noon, and of the latter from 0 to 12 A.M. and

P.M. At Washington, on the other hand, M. de Struve, on behalf of the delegates from Russia, considered it desirable that both universal and local time should be reckoned from 0^h to 24^h, and that the former should start with midnight of the initial meridian, so that for nearly the whole of the inhabited parts of the world the difference of date between local and universal time would not fall during the principal business hours of the day. Mr. W. F. Allen, Secretary of the Railway Time Convention of the United States and Canada, argued from the experience of Great Britain, Sweden, the United States, and Canada, that standard time, differing by an exact number of hours from universal time, could practically be adopted all over the world, and that therefore it was not necessary, as had been maintained at Rome, to retain exact local time side by side with universal time. He stated that the new standards of time 5^h, 6^h, 7^h, and 8^h slow on Greenwich, had been already adopted by nearly 85 per cent. of the total number of cities of over ten thousand inhabitants in the United States, and that it was used on 120,000 miles of railway in the United States and Canada, being $97\frac{1}{2}$ per cent. of the total mileage. As affecting astronomers and navigators, both Professor Adams and Commander Sampson, U.S.N., preferred to commence the universal day at midnight, as proposed by Mr. Rutherford, and in this view they were supported by Professor W. Valentiner and Professor Hilgard. Admiral Rodgers, U.S.N., the President of the Conference, added that it was already the practice in the U.S. Navy to reckon the day from midnight.

In explanation of the circumstance that the delegates of many of the European States abstained from voting on Nos. III. and V. of the Washington resolutions, it is to be remarked that Austria-Hungary, Germany, Italy, Netherlands, Spain, Sweden, and Switzerland were only represented by diplomatists, who were understood to have received instructions from their respective Governments simply to vote for the recommendations of the Geodetic Conference at Rome.

The British delegates at Washington were Professor J. C. Adams; Captain Sir F. J. O. Evans, R.N.; Lieut.-Gen. Strachey, R.E. (representing India); and Mr. Sandford Fleming (representing Canada).

Telegraphic Longitudes in Australia and New Zealand.

It had formed part of the programme of the Transit of *Venus* 1882 Expeditions to Australia that the longitudes of the principal Observatories on that continent should be determined, taking as a starting-point the station at Singapore, which was connected with Madras in 1870 by Professor Oudemans. Early in 1883 Captain Darwin, R.E., proceeded to Singapore with a transit instrument and clock. At the same time Mr. Baracchi,

an assistant at the Melbourne Observatory, went to Port Darwin similarly equipped. Both these gentlemen had previously compared their mode of observing with the principal observers at Adelaide and Melbourne, and Captain Darwin at Sydney also.

Signals were successfully exchanged through the cables between Singapore and Port Darwin, and between Port Darwin and the Observatories of Adelaide and Melbourne independently through an immense length of land line. The details of the various operations have not yet been published, but the very approximate results are known.*

In the same year the longitude of the Survey Observatory, Mount Cook, Wellington, New Zealand, was determined by Mr. Russell at Sydney and Mr. Adams at Wellington, the latter gentleman, acting under the direction of the surveyor-general of New Zealand, having first visited Sydney in order to compare himself, in observing transits, with the observers there. The whole of Mr. Adams' careful observations for local time are published in detail,† and it is much to be regretted that no information of a similar kind is supplied from Sydney Observatory.

The following are the results of these operations, the longitudes being all east of the Royal Observatory, Greenwich :—

	h	m	s
Starting Point, Flagstaff, Government Hill, Singapore, Professor Oudemans' in 1870	6	55	22·71
Port Darwin (Baracchi's Station)	8	43	21·74
Adelaide Observatory	9	14	19·61
Melbourne Observatory	9	39	53·38
Sydney Observatory	10	4	48·47
Mount Cook Observatory, Wellington	11	39	5·46

* Mr. Charles Todd in *Observatory*, 1883 October; also "Report of Surveyor-General of New Zealand," 1883–84.

† *Loc. cit.*

Papers read before the Society from February 1884 *to February* 1885.

1884.

Mar. 14. Variation in the light of *Neptune*. Maxwell Hall.

Note on Professor Adams's paper in the *Monthly Notices* for December 1883. E. J. Stone.

Additional note on the change of the unit of time. Professor A. Cayley.

Spectroscopic observations of Comet Pons-Brooks. Dr. N. de Konkoly.

Spectroscopic observations of the red-coloured sky at sunset. Dr. N. de Konkoly.

Electric illumination of spectroscope micrometers. Dr. N. de Konkoly.

On a new colorimeter, serving as a spectral photometer. R. de Kövesligethy.

Some remarks on the spectroscopic determination of the motions of Stars in the line of sight. R. de Kövesligethy.

Remarks on Major-General Tennant's paper "On the change in the adopted unit of time." Professor J. C. Adams.

A general law of Planetary and Cometary motion in the Solar System. Professor C. V. Zenger.

Observations of occultations of Stars by the Moon, and of phenomena of *Jupiter's* Satellites made at the Davidson Observatory, San Francisco, and at Table Mount Station, California. Geo. Davidson.

Remarks on Mr. Hilger's illumination of micrometers by vacuum tubes. Dr. N. de Konkoly.

Observations of Sun-spot spectra in 1883. Rev. S. J. Perry.

Phenomena of *Jupiter's* satellites observed at Stonyhurst in 1883. Rev. S. J. Perry.

Sextant observations of Pons's Comet. Capt. W. L. Rosseter.

Observations of Pons's Comet made at the United States Naval Observatory, Washington. W. T. Sampson and E. Frisby.

The new Comet of 1884 January 12. N. R. Pogson.

Observations of Comet *b* 1883 (Pons-Brooks), made at Vizagapatam. A. V. Nursingrow.

Questions respecting Mr. Stone's theory of a change in the mean Solar day. Professor S. Newcomb.

Remarks on the value of the secular acceleration of the Moon's motion derived from observation. Professor S. Newcomb.

On the necessary distinction in practical astronomy between the true mean Solar day and the mean day adopted, from time to time, in the construction of our Astronomical Tables, and in the comparison of these tables with observations. E. J. Stone.

Sextant observations of Comet *b* 1883 (Pons-Brooks), made at Monte Video. Rev. S. S. O. Morris.

Occultations observed at Forest Lodge, Maresfield. Capt. W. Noble.

Note on the Transit of the fourth Satellite of *Jupiter*, 1884 March 12. E. J. Spitta.

Note on the determination of the Planes of the Orbits of *Jupiter's* Satellites. A. Marth.

Remarques sur les "Notes on Nyrén's determination of the constant of aberration," de M. Gill. M. Nyrén.

Observations of the occultation of *Venus* by the Moon, made at the Royal Observatory, Greenwich, 1884 February 29. Communicated by the Astronomer Royal.

On an instance of change of personality in observing position-angles of Double Stars, and on the orbit of *α Centauri*. A. M. W. Downing.

Suggestions for improvements in the construction of large Transit Circles. A. A. Common.

The parallax of *α Tauri*. Professor O. Struve.

April 9. A method for clearing a lunar distance. J. Merrifield.

Notes on Nyrén's determination of the constant of aberration. David Gill.

Observations of Comet *a* 1884, made at Windsor, New South Wales. J. Tebbutt.

Some remarks on the chain of Meridian distances measured around the earth by H.M.S. "Beagle," between the years 1831 and 1836. Professor A. Auwers.

The radiant points of fireballs. W. F. Denning.

A new dark field micrometer, and electric illumination of Equatorial at Melbourne. R. L. J. Ellery.

Observations of Comet Ross, made at the Observatory, Melbourne. R. L. J. Ellery.

Occultations of λ *Geminorum* and κ *Cancri*. Henry Pratt.

Abnormal appearance of *Jupiter's* Satellite iv., while in Transit on March 12. Henry Pratt.

May 9. Elements of the Orbit of Comet *a* 1884. J. Tebbutt.

The Orbit of Pons's Comet. Dr. J. Morrison.

Observations made at the United States Naval Observatory, Washington. Professor A. Hall.

The motion of *Hyperion*. Professor A. Hall.

Sextant observations of Comet Pons-Brooks, made on board the ship "Earnock." Capt. G. F. Parson.

Observations of the companion of *Sirius*, made at the Dearborn Observatory, Chicago. Professor G. W. Hough and S. W. Burnham.

On the occultation of κ *Cancri*. Dr. C. L. Prince.

On the corrections required by Hansen's "Tables de la Lune." E. Neison.

Note on Dr. N. de Konkoly's remarks on Mr. Hilger's illumination of micrometers by vacuum tubes. Rev. S. J. Perry.

Note on the eclipse of Thales. J. Maguire.

Sextant observations of Comet Pons-Brooks, made on board the ship "Superb," January and February 1884. Capt. D. W. Barker.

Sextant observations of Comet Pons-Brooks, January 1884. Capt. A. S. Thomson.

On the proper motions of forty Stars in the Pleiades, both absolute and relative. Professor Pritchard.

Observations of *Mars* at the opposition of 1884. E. B. Knobel.

Suggestions for the Improvement of the Transit Circle. Dr. R. Copeland.

The observations of the Moon made at the Radcliffe Observatory during the year 1883, and a comparison of the results with the tabular places from Hansen's Lunar Tables. E. J. Stone.

Note on a method of reducing the friction of the polar axis of a large telescope. A. A. Common.

June 13. Fourth catalogue of micrometrical measures of Double Stars made at the Temple Observatory, Rugby. G. M. Seabroke.

On a new Variable Star in *Monoceros*. J. E. Gore.

On the relative proper motions of 40 Stars in the Pleiades determined from micrometric and meridian observations. Professor C. Pritchard.

The Nebula in Orion. R. S. Newall.

Notes on Mr. Stone's explanation of the errors of Hansen's Lunar Tables. Professor S. Newcomb.

The apparent orbit of a Satellite of a superior planet. Dr. J. Morrison.

The physical features of *Saturn*. H. Pratt.

Ephemeris of the Satellite of *Neptune*, 1884–85. A. Marth.

Ephemerides of the Satellites of *Saturn*, 1884–85. A. Marth.

On Professor Newcomb's empirical corrections as a means of restoring an agreement between theory and observation in the case of the Moon. E. J. Stone.

Faint Stars near *Alcyone* and near β^1 and β^2 *Capricorni*. A. A. Common.

Note on the cause of the blurred patches in instantaneous photographs of the Sun. A. C. Ranyard.

Nov. 14. Observations of occultations of Stars by the Moon, 1883–84, and of phenomena of *Jupiter's* Satellites, 1884, made at the Radcliffe Observatory, Oxford. Communicated by E. J. Stone.

Answers to Professor Newcomb's questions on changes in the adopted unit of mean time. E. J. Stone.

Apparent places of Comet II. (Ross) 1883. J. Tebbutt.

Lateral astronomical refraction. H. M. Paul.

Sur une inégalité lunaire à longue période. C. Gogou.

Observations of the Comet of 1812 (Pons-Brooks) at its return to perihelion in 1884. J. Tebbutt.

Ephemerides of the Satellites of *Saturn*, 1884–85 (continuation). A. Marth.

Ephemerides for physical observations of *Jupiter*, 1884–85. A. Marth.

Sextant observations of Comet Pons-Brooks made on board the ship "British Envoy." Capt. P. Holdich.

Abnormal obscurity of the Moon in the late eclipse. Rev. S. J. Johnson.

The total eclipse of the Moon, 1884 October 4. W. F. Denning.

Observations of Comet Barnard 1884. J. Tebbutt.

Occultations of Stars by the Moon observed at the Davidson Observatory, San Francisco. G. Davidson.

Observations of Comet 1884 (Barnard), made at the Royal Observatory, Cape of Good Hope.

Approximate elements of Comet, 1884 (Barnard). W. H. Finlay.

The occulting eye-piece. E. J. Spitta.

A remarkable configuration of Stars in the Milky Way detected by photography. Rev. T. E. Espin.

On the periodic time of *α Centauri*. E. B. Powell.

A photometric comparison of t light transmitted by certain refracting and reflecting telescopes of equal aperture. Professor C. Pritchard.

Note on a comparison of the photometric magnitudes of the same Stars observed at Harvard College and at the University Observatory, Oxford. Professor C. Pritchard.

Observations of Stars occulted by the Moon during the eclipse of 1884 October 4. Communicated by Professor Pritchard.

The proper motions of the 460 Stars given in the R.A.S. *Memoirs*, vol. xxiii., when the places of Auwers's re-reduction of Bradley's observations are

adopted instead of Bessel's, with notes on the proper motion of μ *Piscium*. E. J. Stone.

Total eclipse of the Moon, 1884 Oct. 4. Communicated by E. J. Stone.

Occultations of Stars observed at Dun Echt during the total lunar eclipse of Oct. 4, 1884. Dr. R. Copeland.

Total eclipse of the Moon, October 4, 1884. Rev. S. J. Perry.

Note on a method of giving long exposures in astronomical photography. A. A. Common.

Note on stellar photography. A. A. Common.

The orbit of Barnard's Comet 1884. Dr. J. Morrison.

Occultations observed at Harrow during the total eclipse of the Moon, 1884 October 4. Lieut.-Col. Tupman.

On a new solar eye-piece. A. Hilger.

Dec. 12. Observations of Comet *c* 1884 (Wolf), made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

On the numerical value of the coefficient of Neison's long inequality in the Moon's motion, due to the action of Mars. [Extract from a letter to Professor Adams.] C. Gogou.

On systematic errors in the reading of the circle-microscopes of the Cape Transit Circle. David Gill.

Note upon the Right Ascensions of certain standard polar Stars. Professor T. H. Safford.

Data for a graphical representation of the Solar System. A. Marth.

Spectroscopic observations made at the Earl of Crawford's Observatory, Dun Echt. R. Copeland.

Observations of Comets Pons-Brooks and Ross, 1884. A. B. Biggs.

The long duration of meteor radiant points. W. F. Denning.

1885.

Jan. 9. Ephemeris for finding the positions of the Satellites of *Uranus*, 1885. A. Marth.

Note on Professor Pritchard's comparison of the light transmitted by refracting and reflecting telescopes. W. S. Franks.

Occultations of Stars by the Moon, and phenomena of the Satellites of *Jupiter* and *Saturn*, observed at Mr. Edward Crossley's Observatory, Bermerside, Halifax, in the year 1884. J. Gledhill.

Observations of Stars occulted by the Moon during the eclipse of 1884 October 4. E. J. Spitta.

Note on an observation of *Saturn*, November 23, 1884. E. J. Spitta.

On screw-wear as affecting the N.P.D. of the Cape Catalogue for 1880. E. J. Stone.

The observations of the Moon made at the Radcliffe Observatory during the year 1884, and a comparison of the results with the tabular places from Hansen's Lunar Tables. E. J. Stone.

Note on the descriptions of two Stars in Ptolemy's Catalogue. E. B. Knobel.

Observations of occultations of Stars by the Moon, and of phenomena of *Jupiter's* Satellites, made at the Royal Observatory, Greenwich, in the year 1884. Communicated by the Astronomer Royal.

Note on the periodic time of *α Centauri*. A. M. W. Downing.

Observations of Comet *c* 1884 (Wolf), made at Stonyhurst College Observatory with the 8-inch telescope and ring micrometer. Rev. Ad. Müller.

List of Public Institutions and of Persons who have contributed to the Library, &c. since the last Anniversary.

Her Majesty's Government.
Her Majesty's Government in Australia.
Her Majesty's Government in India.
The Norwegian Government.
The Lords Commissioners of the Admiralty.
British Association for the Advancement of Science.
British Horological Institute.
Geological Society of London.
Institute of Civil Engineers.
Meteorological Office.
Photographic Society of Great Britain.
Physical Society of London.
Royal Asiatic Society of Great Britain.
Royal Geographical Society.
Royal Institution of Great Britain.
Royal Meteorological Society.
Royal Observatory, Greenwich.
Royal Society of London.
Royal United Service Institution.
Society of Arts.
University College, London.
Zoological Society of London.
Belfast Natural History and Philosophical Society.
Birmingham Philosophical Society.
Birmingham, Mason Science College.
Bristol Museum and Library.
Dublin, Royal Irish Academy.
Dublin, Royal Society.
Dunsink Observatory.
Edinburgh, Royal Society.
Glasgow Observatory.
Glasgow Philosophical Society.
Kew Observatory.
Leeds Philosophical and Literary Society.
Liverpool Astronomical Society.
Manchester Literary and Philosophical Society.
Oxford, Radcliffe Observatory.
Rugby School Natural History Society.
Adelaide Observatory.
Adelaide, Royal Society of South Australia.

Amsterdam, Royal Academy of Sciences.
Baltimore, Johns Hopkins University.
Batavia, Magnetical and Meteorological Observatory.
Batavia, Royal Society of Sciences.
Berlin, International Geodesic Association.
Berlin, Royal Academy of Sciences.
Berlin, Royal Observatory.
Berlin, Royal Prussian Geodetic Institute.
Berne University.
Bologna, Academy of Sciences.
Bombay Branch of the Royal Asiatic Society.
Bordeaux, Society of Physical and Natural Sciences.
Boston, American Academy of Arts and Sciences.
Brussels, Royal Observatory.
Buda-Pesth, Hungarian Academy of Sciences.
Calcutta, Asiatic Society of Bengal.
Chicago, Dearborn Observatory.
Cincinnati Observatory.
Copenhagen, Royal Academy of Sciences.
Cordoba, Argentine National Observatory.
Geneva Observatory.
Göttingen, Royal Society of Sciences.
Haarlem, Musée Teyler.
Halle, Imperial Leopold-Caroline Academy.
Hamilton Association.
Harvard College Astronomical Observatory.
Helsingfors, Finnish Society of Sciences.
Helsingfors Observatory.
Karlsruhe Observatory.
Kasan, Imperial University.
Leipzig, Astronomische Gesellschaft.
Leipzig, Royal Saxon Society of Sciences.
Leyden, École Polytechnique.
Madison, Washburn Observatory.
Madras Observatory.
Melbourne Observatory.
Melbourne, Royal Society of Victoria.
Milan, Royal Observatory.
Moncalieri Observatory.
Montreal, Royal Society of Canada.
Moscow Observatory.
Munich, Royal Bavarian Academy of Sciences.
Natal Observatory.
Neuchatel, Society of Natural Sciences.
New Haven, Connecticut Academy of Arts and Sciences.
New York, Columbia College.
Ottawa, Canadian Meteorological Office.
Palermo Observatory.
Paris, Academy of Sciences.
Paris, Bureau des Longitudes.

Paris, Dépôt Général de la Marine.
Paris, International Committee of Weights and Measures.
Paris, Mathematical Society of France.
Paris Observatory.
Paris, Philomathic Society of France.
Philadelphia, American Philosophical Society.
Philadelphia, Franklin Institute.
Prague Observatory.
Pulkowa Observatory.
Rio de Janeiro, Imperial Observatory.
Rome, Central Meteorological Office.
Rome, Italian Society of Sciences.
Rome, Italian Spectroscopic Society.
Rome, Pontifical Academy dei Lincei.
Rome, Royal Academy dei Lincei.
St. Petersburg, Imperial Academy of Sciences.
St. Petersburg, International Polar Commission.
Santiago Observatory.
Sydney, Government Observatory.
Sydney, Royal Society of New South Wales.
Tacubaya Observatory, Mexico.
Tasmania, Royal Society.
Tokio University.
Toronto, Canadian Institute.
Toronto Observatory.
Toulouse, Academy of Sciences.
Turin, Italian Meteorological Association.
Turin, Observatory of the Royal University.
Turin, Royal Academy of Sciences.
Upsala, Royal Society of Sciences.
Vienna, Imperial Academy of Sciences.
Washington, Bureau of Navigation.
Washington, Office of the American Ephemeris.
Washington, National Academy of Sciences.
Washington Philosophical Society.
Washington, Smithsonian Institution.
Washington, United States Chief Signal Office.
Washington, United States Coast and Geodetic Survey.
Washington, United States Naval Observatory.
Yale College Observatory.
Yokohama, Seismological Society of Japan.
Zurich Central Meteorological Association.
Editors of the American Journal of Science.
Editors of the American Journal of Mathematics.
Editor of the Astronomical Register.
Editor of the Astronomische Nachrichten.
Editor of the Athenæum.
Editors of the Bulletin des Sciences Mathématiques, &c.
Editor of the English Mechanic.
Editor of the Journal of Science.

Editor of Die Naturforscher.
Editor of The Observatory.
Editor of Science.
Editor of the Sidereal Messenger.
Editor of Sirius.

Signor A. Abetti.
Dr. E. Becker.
L. H. Beebe, Esq.
Dr. O. Boeddicker.
Prof. Th. Bredichin.
J. Rand Capron, Esq.
Signor E. G. Celoria.
H. J. Chaney, Esq.
P. E. Chase, Esq.
Latimer Clark, Esq.
A. A. Common, Esq.
The Earl of Crawford.
Mdlle. Dembowski.
C. L. Doolittle, Esq.
R. L. J. Ellery, Esq.
Dr. F. Engström.
M. H. Faye.
Padre G. S. Ferrari.
M. C. Flammarion.
E. L. de Forest, Esq.
M. E. Gautier.
Dr. F. K. Ginzel.
J. E. Gore, Esq.
Herr A. von Gothard.
Herr E. von Gothard.
Dr. B. A. Gould.
Dr. E. von Haerdtl.
M. P. Henry.
Prof. J. C. Houzeau.
Dr. J. A. Kleiber.
E. B. Knobel, Esq.
Dr. N. von Konkoly.
Le Père M. Lamey.
Dr. J. Lamp.
Prof. S. P. Langley.
Capt. S. T. S. Lecky.
R. J. Lecky, Esq.
Herr B. Max Lersch.
M. M. Loewy.
E. Loomis, Esq.
Prof. G. Lorenzoni.
F. G. T. Lueders, Esq.
W. T. Lynn, Esq.
Señor R. Mallen.
Dr. W. Meyer.
Signor E. Millosevich.
M. Ch. Montigny.
Signor A. Nobile.
A. V. Nursingrow, Esq.
O. T. Olsen, Esq.
Prof. J. A. C. Oudemans.
Dr. C. F. Pechüle.
W. Peck, Esq.
J. D. Perrins, Esq.
Rev. S. J. Perry.
Prof. C. F. W. Peters.
H. Pratt, Esq.
C. L. Prince, Esq.
A. C. Ranyard, Esq.
M. H. Resal.
H. C. Russell, Esq.
H. Sadler, Esq.
J. M. Schaeberle, Esq.
A. Searle, Esq.
Dr. H. Seeliger.
John Service, Esq.
Prof. C. Piazzi Smyth.
E. J. Spitta, Esq.
Prof. O. von Struve.
Señor J. de M. Tamborrel.
D. P. Todd, Esq.
W. C. Winlock, Esq.
M. C. Wolf.
Dr. R. Wolf.
Prof. C. A. Young.

ADDRESS

Delivered by the President, Edwin Dunkin, F.R.S., on presenting the Gold Medal of the Society to William Huggins, D.C.L., LL.D., F.R.S.

Gentlemen,

You have already been informed in the Annual Report, just read, that the Council have awarded the Gold Medal of the Society to Dr. William Huggins for his researches on the motions of stars in the line of sight, and on the photographic spectra of stars and comets. It now becomes my pleasing duty to explain to you briefly, in a general manner, the principal grounds by which the Council have been influenced in coming to their decision.

Before doing so, however, perhaps I may be permitted to remark that no one can possibly refer to the printed list of our medallists without being impressed with the wideness of scope available to the astronomical inquirer, as illustrated by the great diversity of subjects for which the medal has been awarded by the respective Councils in past years. A glance at the names contained in the printed list shows clearly that the medals of the Society have been presented to astronomers without regard to nationality or to subject, for their original researches either in the mathematics, the ordinary observing labours, or in the literature of astronomy. For instance, I do not find that profound researches on the theories of the movements of the members of the Solar System, or on kindred mathematical subjects, have been more recognised than those relating to important tabular deductions from meridian or equatorial observations, to the original discoveries of planets and comets, or to many other miscellaneous subjects in the more popular branches of the science. On the contrary, since the first award in 1823 to the present time, original inquirers in all branches of astronomy have been found worthy recipients of our medal, a sufficient evidence of the strict impartiality of the Council. But it must be borne in mind that this, the highest scientific honour that the Society can bestow, has never been presented to anyone before his claims have been well weighed by those who, for the time being, have been the Society's representatives. The chief object of the Council, so far as my experience goes, has always been the endeavour to recognise the original works of astronomers generally whenever

any specially high merit is exhibited, or a definite advance on some point in astronomy is made; and I believe in a remark made by Sir George Airy, that "Scarcely ever has it occurred that in looking back to the award of our medals we could say that any important subject had been omitted which ought to have been taken into consideration, or that a better choice could have been made than that which we have made."

As you are all doubtless aware, the Society's gold medal was awarded in 1867 to Dr. Huggins, jointly with Dr. W. Allen Miller, for their researches in astronomical physics. The grounds for this award are most ably and eloquently given in the address of the President, Professor C. Pritchard, and I consider that I cannot do better than refer you to that address, not only for numerous details connected with the labours of these gentlemen, given with all that earnestness of language of which the author is so consummate a master, but also for an interesting, though brief, account of the progress of spectrum analysis as applied to the examination of the physical constitution of the heavenly bodies from the time when Dr. Wollaston, in 1802, first observed a few of the principal lines in the solar spectrum. I thus refer you to Professor Pritchard's address, as, in the few remarks which it will be my duty to make, I shall naturally confine myself to those observations of Dr. Huggins made subsequently to 1867, and more particularly to the special subjects named in the award, referring to his original experimental researches relating to his method for determining the motions of stars in the line of sight, and to his successful photographs of the spectra of stars and comets.

Although Dr. Huggins's first published memoir on his method of determining the relative radial motions of the Earth and stars appeared in 1868, the subject had previously occupied the attention of himself and Dr. Miller so early as 1862; for while engaged in that year on the comparison of the bright lines of terrestrial substances with the dark lines in the spectra of a few of the principal stars, with the object of obtaining information on their chemical composition, their thoughts were also directed to this question of radial stellar motion, for Dr. Huggins has remarked that at the time they were fully aware that "if the stars were moving towards or from the Earth, their motion, compounded with the Earth's motion, would alter to an observer on the Earth the refrangibility of the light emitted by them, and consequently the lines of terrestrial substances would no longer coincide in position in the spectrum with the dark lines produced by the absorption of the vapours of the same substances existing in the stars." (*Phil. Trans.*, 1868, p. 529.) Owing, however, to the insufficiency of the apparatus in these early and delicate experiments, the first results were, on the whole, of a negative character, though enough evidence was obtained to show that better instrumental means only were required to test the method to some definite conclusion. Suffi-

cient, however, was done in the early part of 1868 to enable Dr. Huggins to present, with some confidence, to the Royal Society some observations on a small change of refrangibility which he had observed in a line in the spectrum of *Sirius* when compared with a line of hydrogen. This very small displacement indicated that the star was receding from the Earth in the direction of the line of sight with a velocity of about twenty-nine miles per second.

Dr. Huggins does not claim in any way to be the first to suggest the theoretical idea of using the spectroscope for determining the effects produced by the radial motions of the stars; for I observe that in his memoir, previously quoted, he refers to the researches of Doppler, Fizeau, Clerk-Maxwell, and others who have considered this question. The researches of these physicists, however, all differ in many important respects from those of Dr. Huggins, inasmuch as they refer generally either to the theoretical explanation of the differences of colour usually found in binary stars, or to certain experiments on the influence of the motion of a source of light upon the refrangibility of its rays. The following extract from a letter, addressed to Dr. Huggins in 1867 by the late Professor Clerk-Maxwell, refers specially to M. Fizeau's valuable memoir in the *Annales de Chimie et de Physique*, Feb. 1860. After explaining his own experiments on the influence of the motions of the heavenly bodies on the index of refraction of light, he has stated that "On the other hand, M. Fizeau has observed a difference in the rotation of the plane of polarisation according as the ray travels in the direction of the Earth's motion or in the contrary direction, and M. Ångström has observed a similar difference in phenomena of diffraction. I am not aware that either of these very difficult observations has been confirmed by repetition. In another experiment of M. Fizeau, which seems entitled to greater confidence, he has observed that the propagation of light in a stream of water takes place with greater velocity in the direction in which the water moves than in the opposite direction, but that the acceleration is less than that which would be due to the actual velocity of the water, and that the phenomenon does not occur when air is substituted for water. This experiment seems rather to verify Fresnel's theory of the ether; but the whole question of the state of luminiferous medium near the Earth, and of its connection with gross matter, is very far as yet from being settled by experiment." (*Phil. Trans.*, 1868, p. 535.)

Doppler, in 1841, contended that, as the impression received by the eye and ear is not the result of the strength and period of the waves of light and sound, but that it is rather determined by the interval of time occupied by them in falling upon the eye or the ear of the observer, it follows "that the colour and intensity of an impression of light, and the pitch and strength of a sound, will be altered by a motion of the source of the light or of the sound, or by a motion of the observer, towards or from

each other." By this hypothesis Doppler conceived that he could account for the remarkable variations of colour observed in binary stars. I do not perceive, however, that he or the other physicists, who have investigated the subject, had suggested any trustworthy practical method of observation, by which the absolute amount of approach or recess of stars could be satisfactorily measured. It appears to me, therefore, that this great advance in the subject was reserved for Dr. Huggins, for the undoubted success of the method contrived by him cannot fail to be acknowledged by the results he has given, first in his memoir of 1868, and repeated in that of 1872; results which have been amply confirmed year by year from observations made at the Royal Observatory, Greenwich, at the Observatory of Potsdam, and at other places. To him, therefore, most assuredly belongs the credit of being the first astronomical physicist who gave practical life to the subject, and made the method of observation completely efficient, by which he has added a new element to our knowledge of the system of the universe.

But, gentlemen, I wish you clearly to understand that, successful as Dr. Huggins has been in contriving a method of observation which has been easily followed by independent observers, this success has not been gained without great perseverance on his part, and a determination not to be daunted by any apparent failure. From the first he was evidently convinced in his own mind of the practicability of the method, and that ultimately he would attain sufficiently trustworthy results, which would enable him to announce with confidence that he had really succeeded in measuring the amount of displacement of one of the principal lines in the spectrum of a star, and to determine from that displacement the approximate motion of that star in the line of sight. In experiments of this delicate nature, and probably of most others of a similar kind, we may naturally suppose that the observer, at the beginning of his experiments, is troubled with all sorts of difficulties; and when we consider that so much depends on the steadiness of the atmosphere, or on the accurate adjustment of the spectroscope, the telescope, and other parts of the apparatus employed, can there be any wonder that the first observations are frequently of a negative character? However, sufficient was shown by the early comparisons made by Dr. Huggins to prove that none of the stars, the lines in the spectra of which had been carefully compared, were moving in the direction of the visual ray, relatively to light, equivalent to the displacement of a line through a space equal to that which is observed between the components of Fraunhofer's D. This observation alone was a great advance. But, as I have before remarked, it was not till 1868 that Dr. Huggins, in his communication read before the Royal Society on May 14 of that year, was able to indicate with tolerable certainty a marked, though smaller, displacement of the F line in the spectrum of *Sirius*, which he considered to be the effect pro-

duced by the relative motions of the Earth and Star in the line of sight. As an illustration of the question of what are some of the difficulties experienced in these delicate observations, I think it will be appropriate to quote here the words of Dr. Huggins himself. He says:—"The chief difficulties which I have had to encounter have arisen from the unsteadiness of our atmosphere. There is sufficient light from stars of the first and second magnitude for the large spectroscope, and so far as the adjustments of the instrument are concerned, the lines in the spectra of the stars would be well defined. Unless, however, the air is very steady, the lines are seen too fitfully to permit of any certainty in the determination of coincidences of the degree of delicacy which is attempted in the present investigation. I have passed hours in the attempt to determine the position of a single line, and have then not considered that the numerous observations which I had obtained were possessed, even collectively, of sufficient weight to establish with any certainty the coincidence of the line with the one compared with it." (*Phil. Trans.*, 1868, p. 546.)

All the observations, prior to 1870, were made with the Alvan Clark Refractor of 8 inches aperture and 10 feet focal length, mounted equatorially, and fitted with a clock-movement, which carried the instrument very smoothly. In 1870, the Royal Society placed at the disposal of Dr. Huggins their large Equatorial, constructed by Messrs. Grubb & Son. This instrument is provided with a tube and object-glass of 15 inches aperture, and 15 feet focal length, and also with a second tube containing a speculum of 18 inches diameter. Either of these tubes could be attached, when required, to the declination-axis of the equatorial mounting. In 1882 the instrument was taken down, and remounted in the early part of the following year, with considerable improvements in the mounting of the tubes, which are now attached to two separate declination-axes, the one moving within the other. The two tubes can now be moved in declination independently of each other, and the one not in use can be turned away so as not to be in inconvenient positions. Both are carried by the clock-motion.

The spectroscope which Dr. Huggins had constructed in 1866 for the special objects of his research was furnished with three prisms of 60° of very dense flint-glass, through which the solar lines were very distinctly seen. To obtain a separation of the lines sufficient for his purpose, he found it necessary to employ an eye-piece magnifying ten or twelve times. The stellar lines were not, however, seen in the continued steady manner required for the accurate measurements of the small displacements observed. To obviate this inconvenience, and to ensure success in his observations, Dr. Huggins resolved to employ a larger number of prisms and a smaller magnifying power. He was fortunate in having in his possession two very fine direct-vision prisms on Amici's principle, which induced

him to attempt to combine in one instrument several simple prisms, with one or two compound prisms, which gave direct vision. By this combination of prisms an instrument was devised possessing several not unimportant advantages; but in 1868, after Dr. Huggins's first series of comparisons, an apparatus, superior in many respects to that described in his memoir (*Phil. Trans.* 1868, p. 536), was constructed and afterwards employed in his more recent observations of the displacement of the lines in stellar spectra due to the motions of the stars in the line of sight, and for other spectroscopic work.

For a further detailed account of the peculiar features of the various contrivances adopted by Dr. Huggins in his observations, I must refer you to his original memoirs for these, and for many other interesting particulars, relating to the methods employed, and the many difficulties experienced, in this delicate research, which have led him on step by step towards the successful completion of his original design.

The stars selected by Dr. Huggins in his earlier experiments were mostly those of the first magnitude, including *α Orionis*, *Sirius*, *Aldebaran*, and *Castor*, of all of which comparisons of their spectra were made before 1868; but definite results were only obtained from those of *Sirius* when compared with the F hydrogen line. For my present purpose, therefore, it will be a sufficient example if I confine my remarks wholly to that star, whose resulting radial motion was the first confidently announced as a proof of the adequacy of the method of comparison. The subject was soon taken up at other Observatories, and its principle, for the most part, confirmed.

As Dr. Huggins and Dr. Miller had previously concluded that the strong lines in the spectrum of *Sirius* were due to the presence of hydrogen, the F line was used generally in the comparisons. At the time when the observation of the displacement of this line was made by Dr. Huggins, the amount of the change of refrangibility was in wave-length 0·109 millionth of a millimetre. Assuming the velocity of light to be 185,000 miles per second, and the wave-length of F 486·50 millionths of a millimetre, it was found that the observed displacement of this line in *Sirius* would indicate a motion of recession from the Earth of 41·4 miles per second. When this observation was made, it appeared that the Earth was moving with a velocity of about 12 miles per second, from which it has been inferred that, of the combined recession of 41·4 miles per second between the Earth and the Star, 29·4 miles per second may be attributed to the motion of *Sirius* in the line of sight at that period.

Fortified with new instrumental means of the highest order, Dr. Huggins resumed his inquiry in the spring of 1872, and during a few nights sufficiently fine for these delicate comparisons, he was able to make several series of measures of the amount of displacement of the F line in the spectrum of *Sirius* with the corresponding line in the spectrum of hydrogen. This set of

observations completely confirmed the former conclusion that the star was receding from the Earth, but with a much smaller velocity; for whereas in 1868 the observed absolute radial motion of the star was found to be 29·4 miles per second, the motion determined in 1872 was from 18 to 22 miles per second. Dr. Huggins has observed on this apparent diminution of velocity that "the difference of this estimate, which is probably below rather than in excess of the true amount, from that which I formerly made may be due in part or entirely to the less perfect instruments then at my command. At the same time, if *Sirius* be moving in an elliptic orbit, as suggested by Dr. Peters, that part of the star's proper motion which is in the direction of the visual ray would constantly vary." More recent observations made at the Royal Observatory would seem to confirm this apparent change of velocity, and that the original estimate in 1868 was at the time not far from the truth. It is remarkable that a nearly constant diminution of the recession has been recorded in the Greenwich Observations from year to year, till at the present time a considerable approach towards the Sun is indicated.*

In addition to *Sirius*, the stars found by Dr. Huggins in 1872 to be receding from the Sun are *Rigel*, *α Orionis*, *Castor*, *Regulus*, and *β*, *γ*, *δ*, *ε*, and *ζ Ursæ Majoris*, while those found to be approaching the Sun are *Pollux*, *α Ursæ Majoris*, *Arcturus*,

* Through the courtesy of the Astronomer Royal, I am enabled to give in the following table the mean concluded radial motion of *Sirius*, observed at the Royal Observatory at each opposition. The measures from 1875 to the spring of 1877 were obtained with the old ten-prism spectroscope, and extended over the period from December 22, 1875 to March 17, 1877. The other measures were all obtained with the half-prism spectroscope. The years given in the first column refer to the winter season common to both years; for instance, 1877–78 means that the observations were made during the winter from November 1877 to March 1878.

Motion of Sirius in the Line of Sight, from Observations made with the Spectroscope at the Royal Observatory, Greenwich.

Opposition of	Number of Nights.	Number of Measures.	Mean Concluded Motion.
1875–76 and 1876–77	4	8	+21·1 miles per sec.
1877–78	3	8	+23·0 „
1879–80	3	10	+15·1 „
1880–81	2	4	+11·3 „
1881–82	5	22	+ 2·1 „
1882–83	3	18	− 4·7 „
1883–84	13	43	−19·4 „
1884–85	2	8	−21·5 „

In the last column the sign + denotes recession from the Sun, and the sign − approach towards the Sun.

α Lyræ, and *α Cygni*, omitting many others which indicate either recession or approach, but which had been deferred for further observation.

I have no doubt that many of the Fellows will be interested to learn that observations for the determination of the motions of stars in the line of sight now form a most important branch of the daily work in the Physical department of the Royal Observatory whenever the state of the sky permits. The results have been communicated to the Society, and they appear annually in the *Monthly Notices*. In one year, 1883, the observed amount of the displacement of usually the F or b_1 lines is given for 46 stars, of many of which the observations were made on several nights during the year. The total number of measures were 310.* The absolute results of approach or recession of corresponding stars deduced by Dr. Huggins and at the Royal Observatory have been compared by the present Astronomer Royal. The agreement between the two series of concluded values is most satisfactory, and, considering the great delicacy of the observations, the discordances are not greater than might have been expected. Some of these comparisons have been communicated to the Society by Mr. Christie, who has remarked that, notwithstanding the difficulty of observation, "it is gratifying to find that, out of the list of 21 stars which have been observed, both by Dr. Huggins and Mr. Maunder, there are only two cases of discordance, as will be seen from the table; and for both of these stars Dr. Huggins has expressed himself as dissatisfied with his observations; whilst the Greenwich results for these stars rest on too few observations at present." (*Monthly Notices*, vol. xxxvi. p. 316.) The observations of these and other stars made at Greenwich in subsequent years to the date of that communication give also generally accordant results. (*Monthly Notices*, vol. xxxviii. p. 507.)

I cannot conclude this portion of my address more appropriately than by giving the independent testimony of my late revered friend, Mr. Spottiswoode, on presenting the Rumford Medal to Dr. Huggins at the anniversary meeting of the Royal Society on November 30, 1880. I give it in his own words: "Dr. Huggins has determined the radial component of the velocity of the heavenly bodies relatively to our Earth, by

* Since writing the above, I find from the Council Report of the Proceedings of the Royal Observatory that these numbers were far exceeded in 1884, when 731 measures of displacement of either the F or *b* lines were observed, consisting of 674 measures of the F line in the spectra of 48 stars, 49 of the *b* lines in the spectra of 12 stars, and eight of the F line in the spectrum of the great nebula in *Orion*. In addition to these measures, 132 comparisons of the hydrogen or magnesium lines, with the corresponding lines in the spectrum of the Moon, were made as a check on the general accuracy of the concluded results of the absolute motions of the stars in the line of sight. Several measures of the displacement of the F and *b* lines in the spectra of *Venus* and *Mars*, and some observations of the relative displacement of the same lines at the east and west limbs of *Jupiter*, were also made for the same purpose.

means of the alteration of the refrangibility of certain definite kinds of light which they emit, or which are stopped by their atmospheres. The smallness of the alteration corresponding to a relative velocity comparable with the velocity of the Earth in its orbit makes the determination a matter of extreme delicacy. But as early as 1868, he had obtained such trustworthy determinations, that he was able to announce before the Royal Society that *Sirius* was receding from our Solar System with a velocity of about 29·4 miles per second. In a paper presented to the Royal Society in 1872, he has given the results obtained for a large number of stars, and has shown that some are receding and some approaching, and that there seems to be a balance of recession in those parts of the heavens, from which we have reason, from the observed proper motions, which of course can only be transversal, to conclude that the Solar System is receding, and a balance in favour of approach in the opposite direction; while yet it does not appear that the motion of the Solar System would alone account for the whole of the proper motions of the stars in a radial direction.

"The same inquiry was extended to the nebulæ, the spectrum of which consists of bright lines, and in this case it presented greater difficulties. As those nebular lines, which appear pretty certainly to be identifiable with hydrogen, are too faint to be employed in the investigation, and the others are not at present identified with those of any known element or compound, he was obliged to avail himself of a coincidence between the brightest nebular line and a line of lead. But as the coincidence is probably merely fortuitous, the results give only the *differences* of approach or recess of different nebulæ. The observations seem to show that, so far as has been observed, the nebulæ are objects of greater fixity as regards motion in space, than the stars."

Though I believe that it is no part of my duty, on the present occasion, to refer to any other researches of Dr. Huggins than those contained strictly within the grounds of the award, still, I consider that it is only proper that I should draw your attention to the subjects, at least, of some of his more important contributions to astronomical physics, which have been published since 1867. My remarks on them must, however, be very brief, but the full details of each will be found either in the *Philosophical Transactions* or *Proceedings* of the Royal Society, and in some other publications.

One of the first investigations which Dr. Huggins undertook after the erection of the Royal Society Equatorial, was the determination of the true character of the bright lines in the spectra of the nebulæ, one of which was found to be probably coincident with that of nitrogen. His paper on his eye observations of the great nebula in *Orion* gives a detailed description of the character and position of the four bright lines: the first of which he was inclined to regard as probably due to nitrogen; the second

line was found to be a little less refrangible than a strong line in the spectrum of barium, but the substance to which it belongs is doubtful; while the third and fourth lines agree in position with two lines in the spectrum of hydrogen at F and near G. An estimation was made of the probable motion of the nebula in the line of sight; and if the amount of displacement of the first nebular line from the middle of the double line of nitrogen is correct, it would correspond to a velocity of 55 miles per second from the Earth, or, taking into account the Earth's orbital motion, a recession of 40 miles per second from the Solar System is indicated. From the difficulty of the observation, this result is not given by Dr. Huggins as final, as he remarks that it is possible that the first line in the spectrum of the gaseous nebulæ is not due to nitrogen at all, and that "in consequence of the uncertainty of the character of this first line, which is single, while that of nitrogen is double, this determination can now only be made by means of the comparison of the third line with that of hydrogen. The third line becomes very faint from the great loss of light unavoidable in a spectroscope that gives a sufficient dispersive power, and the comparison can only be attempted when the sky is very clear and the nebula near the meridian." Dr. Huggins's observations of the spectra of Brorsen's Comet, and Comet II. 1868, are highly important. The three bands observed in the spectrum of the latter comet, though in similar parts of the spectrum as the three bands in Brorsen's Comet, differed considerably from them in position and character. By a direct comparison in the instrument with the spectrum of olefiant gas, the bands of Comet II. 1868 were found to be identical in refrangibility, and in other respects, with the bands in the spectrum of carbon. The spectra of Comet I. 1871, and Encke's Comet in the same year, were also examined.

Soon after the great solar eclipse of August 18, 1868, you will remember that considerable interest was excited among physical astronomers when the information was received in England that the spectroscopic observations of the red prominences showed that their spectra were discontinuous, and that, at least, three bright lines were observed. This interest was much increased when the simultaneous announcement was made, at a meeting of the Académie des Sciences in the autumn of 1868, that M. Janssen on the day following the eclipse, and Mr. Lockyer a few weeks after, had each independently succeeded in viewing the spectrum of a prominence in daylight. Before this eclipse attempts were made by several observers for the same object, and among them Dr. Huggins, but without success. But shortly afterwards, having now some indication of the position of the bright lines, he saw the spectra of the promine ces at once with a small spectroscope, with which they had been previously looked for in vain. The subject for some time continued to occupy his attention, and in the following

year he communicated to the Royal Society a short paper on a method of viewing the *forms* of the prominences by means of a wide slit, the method which has since been generally in use.

Time will not allow me to refer to other short, but interesting and valuable, papers of Dr. Huggins, as I must now proceed to the second subject named in the award, and consider some of his more recent labours on the photographic spectra of stars and comets.

The successful application of photography for the delineation of celestial objects has done much to give us a clearer conception of their peculiar features and constitution. My predecessor in this Chair, at the last anniversary meeting, had the gratifying duty of recognising, on the part of the Council, their just appreciation of the finest specimen as yet produced of the details of the great nebula in *Orion*, as photographed by Mr. Common, a work which, as Mr. Stone truly remarked, has "excited the admiration of all the astronomers who had an opportunity of inspecting it." But photography has also given us the beautiful representations of the lunar face, for which we are indebted to Mr. De La Rue and many others; of numerous celestial objects, including the photographs of the late Dr. Henry Draper, who was following, in some measure, the same line of research as Dr. Huggins; of the pictures of the great Comet of 1882 and the neighbouring stars, photographed at the Cape Observatory; and of some recent beautiful photographs of stars to the ninth magnitude, near θ *Orionis* and α *Aquilæ*, taken by Mr. Common. In Mr. De La Rue's photographs of the solar eclipse of 1860, we have undoubtedly the first recorded proof of the solar origin of the red prominences. No one can deny that these brilliant results, produced by the aid of the camera, are of the highest scientific importance, although I believe that the future of photographic astronomy will exhibit a history that will far transcend what has been accomplished in the past; and that the time will come—it may not be far distant—when astronomy will be enriched even with a photographic stellar atlas, which will contain not only a classified arrangement of the positions and magnitudes of the stars, but also an indication of the probable material elements of which the larger stars are composed. As the commencement of such a work, the photographic observations of the spectra of the stars, by Dr. Huggins, will always command an honourable place.

Although the subject of photographing the spectra of some of the principal stars was only systematically taken up by Dr. Huggins since the erection of the Royal Society equatorial, he had, nevertheless, planned a series of observations more than twenty years ago. With his friend and colleague, Dr. W. A. Miller, they had jointly succeeded in obtaining a photograph of the spectrum of *Sirius*, which was exhibited to the public on a screen at a lecture delivered at the Royal Institution in 1863. Previously to this the images of the stars had been photographed

as points, but the spectrum exhibited was the first instance that the rays of a star after dispersion were recorded upon a photographic plate. Though extremely interesting and valuable as a preliminary experiment, these photographs were not of sufficient clearness to be of scientific value, a defect which was partly due to the action of the driving-clock, which did not work with the required accuracy. The observations, therefore, were for a time discontinued.

In December, 1876, Dr. Huggins communicated to the Royal Society a preliminary "Note on the Photographic Spectra of Stars" (*Proceedings*, vol. xxv., p. 445), in which he states that he had recently resumed these experiments, using for his purpose the 18-inch speculum of the Royal Society equatorial, and that Mr. Howard Grubb had successfully applied to the clock the control of a seconds pendulum in electric connection with a sidereal clock, thus obtaining a sensibly uniform motion of the telescope. From this time the excellent series of photographs of stellar spectra, which Dr. Huggins has taken, may be said to have commenced. As an illustration of the effects of the improvement in his instrumental means, he was able, at this early stage of the inquiry, to give in the above paper an enlarged copy of the spectrum of *α Lyræ*, with a solar spectrum on the same plate, taken on the next day for comparison, the plate having been allowed to remain in the instrument during the interval. Seven strong lines in the spectrum of the star are exhibited on this early photograph, all slightly shaded at the sides. The two lines of least refrangibility coincide in position with two known lines of hydrogen in the solar spectrum. After the publication of this preliminary note, Professor H. Draper contributed two articles on the same subject to the *American Journal of Science*, the first in 1877 and the second in 1879.

The mapping of the photographic spectra of stars, as carried out by Dr. Huggins, is a research of great delicacy, as a perfect definition of the bands is absolutely necessary to allow of the accurate measurement of their respective wave-lengths. It may be supposed that to obtain this satisfactorily the most careful manipulation is requisite, when it is considered that the photographic plates are only $1\frac{1}{2}$ inch long by $\frac{1}{2}$ inch wide, and the length of the photographic spectrum between the lines G and P in the ultra-violet about $\frac{1}{2}$ an inch. The definition is usually very good, and the photographs can very easily be examined, and the position of the lines measured under a low-power microscope; and, though the solar spectrum on the plate is only $\frac{1}{3}$ an inch in length, about fourteen lines may be counted between the lines H and K. The delicacy of the observation arises partly on account of the small quantity of light at the disposal of the observer, and partly to the extreme care required to obtain accurate comparisons of the star spectrum with the spectra of known substances, in order to ascertain whether the presence or absence of such and such substances may be detected in the stars. The general conclusion, from the discussion of the

different spectra, appears to show that the stars may be arranged in a connected series, the various types passing from the class of white stars, through stars more or less resembling our Sun, to the stars which shine with an orange or red light. Dr. Huggins suggests that these types of spectrum probably indicate the relative ages of the stars, or at least their relative temperature.

In Dr. Huggins's complete memoir, read before the Royal Society on December 18, 1879 (*Phil. Trans.*, 1880, pp. 669–690), special notes are given on the peculiarities of the following stars in the first or white group, *Sirius*, *η Ursæ Majoris*, *Spica*, *α Aquilæ*, *α Cygni*, and *α Lyræ*. Photographs were also obtained of several other stars, but owing to the unfavourable state of the atmosphere when they were taken, a description of their spectra is deferred. "The photographs present a spectrum of twelve very strong lines. Beyond these lines a strong continuous spectrum can be traced as far as S, but without any further indication of lines. The least refrangible of these lines is coincident with the line γ of hydrogen near G. The next line in order of greater refrangibility agrees in position with *h* of the solar spectrum. The third line is H; K, if present at all, is thin and inconspicuous. The nine lines which follow do not appear to be coincident with any of the stronger lines of the solar spectrum. These lines appear to be common to all the stars of this class, though it may be that some of the more refrangible lines are sometimes absent." * The usual time of exposure with sensitive gelatine plates was from fifteen minutes to two hours; but in the more recent trials with still more sensitive plates, the period of exposure has been reduced.

In a photograph of the spectrum of *Rigel*, taken on January 3, 1880, all the typical lines can be detected, and they are broader than those found in the spectrum of *α Cygni*, but not so broad as the lines in that of *Spica*. There is also a suspicion of lines beyond the typical group, and of two other lines between α and γ.

Taking *Arcturus* as an example of another type, it is found that it has a photographic spectrum containing a great many lines from *b* to G, and the whole spectrum is crowded with lines as seen in the solar spectrum, which makes a great dissimilarity between its spectrum and that of the class of white stars. Twenty-one of the stronger of these lines have been carefully measured and mapped, and several of them agree in position with corresponding lines in the solar spectrum. Dr. Huggins gives the wave-lengths of eighty-one lines in the spectrum of this star. On the more refrangible side of *h* the appearance of a bright band is seen which suggests a bright line,

* The observed wave-lengths of the twelve typical lines are :—

	W.L.		W.L.		W.L.
H	4340	β	3834	ζ	3730
h	4101	γ	3795	η	3717·5
H_1	3968	δ	3767·5	θ	3707·5
α	3887·5	ε	3745·5	ι	3699

on which Dr. Huggins remarks that "After a careful examination of the two negatives which I have of this star, and of positions taken from them, I have come to the conclusion that this appearance is really due to the absence of the finer lines which probably crowd the other parts of the spectrum, though they are too fine and close to be seen separately in the photographs." Beyond K there is a strong contrast in the character of the lines, for they are arranged more or less in triple and other forms of grouping, the lines being much wider and more intense. All the principal lines in the crowded portion of the spectrum have been measured and inserted in the map accompanying the original memoir. I have lately had an opportunity of examining several of the original photographs in each type, and I am glad that I am able to give my unbiassed testimony to the great dissimilarity of the lines in the spectra of the two classes of stars, and also to the exquisite definition of the lines in the photographs of both the solar and stellar spectra.

The spectrum of *Aldebaran*, a pale red star, is also crowded with lines. About fifty of the stronger lines can be measured. In the more refrangible part of the photographed portion of the spectrum the lines are more numerous than in the other portion, and of a different character, being broader, more intense, and apparently more diffused at the edges. The spectrum of *Capella*, though a white star, is a remarkable one, containing a large number of lines, on which Dr. Huggins has remarked that the photographs "exhibit a spectrum from F to beyond S, which so closely resembles the solar spectrum that a photograph of this star would, at first sight, be taken for a solar one," and that this general resemblance of the spectrum of this star with the solar spectrum would seem to indicate that *Capella* is in the same stage as that in which our Sun is.

In addition to these stellar photographs, Dr. Huggins has also taken successful photographs of the spectra of *Venus*, *Mars*, and *Jupiter*, together with a broad daylight spectrum for comparison. They, however, fail to show any additional absorption lines, or any modifications of the solar light in the photographic part of the spectrum. Photographs of the light of the Moon from limited areas of the lunar surface have been taken under different conditions of illumination, and also during partial eclipses of the Moon.

The photographs have been examined and the lines measured by a micrometer attached to a low-power microscope. The measures were then reduced to wave-lengths by the help of solar and terrestrial spectra, with the assistance of Cornu's map of the ultra-violet part of the spectrum, and of Mascart's determinations of the wave-lengths of cadmium. The spectra of *Sirius*, *η Ursæ Majoris*, *Spica*, *α Aquilæ*, *α Lyræ*, *α Cygni*, and *Arcturus*, admit of easy comparison by reference to the map which is laid down on the scale of that of Cornu.

I have already briefly referred to Dr. Huggins's direct eye-observations of the spectra of several comets and to the im-

portant deductions he has obtained from them relating to their physical constitution, but I am now desirous to draw your particular attention to a successful photograph of the spectrum of Comet I., 1882 (Wells), in which the cometary bands differ considerably from those observed in the spectra of previous comets. These bands are exhibited with great clearness in the photograph, an enlarged copy of which may be found in the *Proceedings*, R. S., vol. xxxiv. p. 149. This photograph was taken through one half of the slit on the evening of May 31, 1882, with an exposure of an hour and a half. For the convenience of accurate comparison a spectrum of *α Ursæ Majoris* was taken on the same plate through the other half of the slit. It shows a strong continuous spectrum without the appearance of any of the Fraunhofer lines, extending from about F to a little beyond H. The spectrum differs greatly from that of Comet I. 1881, as also from the spectra of the comets (about twenty) which had been previously examined spectroscopically, and contains bright lines indicating the presence of vapour of sodium, and also some other bright lines and groups of lines. "The continuous spectrum which extends from below F to a little distance beyond H contains at least five brighter spaces, which are doubtless groups of bright lines, though it is not possible in the photograph to resolve them into lines. These places of greater brightness can be traced beyond the border of the continuous spectrum on the side which corresponds to the coma of the comet on the side next the Sun. The light from this part of the comet gave a very much fainter continuous spectrum, for on the photographic plate it appears to be almost wholly resolved by the prisms into these bright groups. One or two fainter groups are suspected to be present, but they are too indistinct to admit of measurement." The beginning and ending of the bright groups are very faint, and the estimated brightest parts only are capable of being measured.

In the photographic spectrum of the great nebula of *Orion*, obtained on March 7, 1882, after an exposure of forty-five minutes, may be noticed five bright lines, as well as a narrower continuous spectrum which Dr. Huggins considers may be due to stellar light. In his previous eye-observation of the spectrum of this nebula he had found four bright lines, the brightest being coincident with the less refrangible component of a strong double line in the spectrum of nitrogen. The second line has a wave-length of 4957 of Ångström's scale, the third and fourth lines being coincident with, as I have already stated, two lines of hydrogen. In the photograph these lines are faint, but they can be satisfactorily recognised and measured. In addition to these the photographic spectrum shows a comparatively strong line in the ultra-violet, corresponding nearly to ζ of the typical spectrum of white stars.

Dr. Huggins's successful application of photography to the subject of these inquiries is now so far acknowledged to be an important astronomical achievement that it is hoped that others will follow his example. But any attempts to follow in his

footsteps will certainly end in failure unless the observer is in possession of instruments of the highest class as well as the necessary zeal for the work. This inquiry into the probable physical constitution of individual stars ought not to be considered completed by Dr. Huggins's experiments, but rather it should be looked upon as the commencement of a research to include the examination and classification of the spectra of all the large stars in both hemispheres. That this will be done sometime in the future I have not the least shadow of a doubt. In the meanwhile we are all able to appreciate the excellent work which our Foreign Secretary has initiated and accomplished.

In conclusion, let us not suppose for one moment that the reliable information we possess at present, relating to the peculiar apparent radial motions and physical constitution of the heavenly bodies, has been obtained without considerable personal and anxious thought on the part of those valued contributors, of different nationalities, who have devoted their time and energy in the prosecution of other delicate researches in spectroscopic astronomy, besides those which form the special subjects of our remarks to-day. I am certain that much early apparent want of success has been felt from time to time by all those physical astronomers who have so nobly enriched our knowledge in this interesting branch of astronomy, since the modern application of the spectroscope to the analysis of the light of the Sun, comets, stars, and nebulæ—a subject of investigation which was first brought prominently into notice by the publication of the remarkable researches of Kirchhoff and Bunsen in the *Memoirs* of the Academy of Berlin, 1861. Among the anxieties to which an observer is liable in delicate observations of this kind, he must always look forward to the many difficulties that are certain to arise at the commencement of a new research, not the least of which are the doubts of ultimate success, or of the astronomical utility of the question under discussion; especially in one, as in the present instance, where the observer is required to possess a good knowledge both of the methods of astronomical observation and experimental chemistry. But where there is a determination to persevere in any well-planned investigation, it is always pleasant to note when, notwithstanding occasional failures, or it may be after seasons of great observing labour and energy on the part of the observer, the anxious inquirer after knowledge conquers all difficulties at last. It often happens in the earlier experiments, as we have previously noticed, that the observer is hampered either by insufficient instrumental means, or by difficulties in obtaining the correct adjustment of the apparatus employed, which, to command success, must be as perfect as possible. But when, by practice, he becomes acquainted with the capability of his instruments, these early difficulties are usually surmounted, and he goes on step by step in his research till he perceives a dawn of light approaching, and, not far distant, the long looked-for results, to attain which he has been so eagerly working, perhaps for years. We

can, in imagination, picture to ourselves the calm satisfaction of the observer when, after carrying on his delicate experiments for a long period, he finds that he is near the end of his self-imposed labours, so that he may soon be in a position to communicate to his colleagues the successful results of his experiments, and to receive from them possibly a due recognition of the scientific value of his work.

But, though we have just seen that difficulties and anxieties may reasonably be expected in all new, and to some extent novel, experiments, let it not be thought that all the early attempts in apparently unsuccessful investigations are entirely thrown away; but, as in the case of our Medallist, who, as we have seen, has had his failures as well as successes, let them rather lead the student of nature onwards to further trials, and, if sincere in his work, he will eventually reap the reward of his zeal and perseverance. If Dr. Huggins, after his comparative failure in 1863 to obtain successful photographs of stellar spectra, or after his inability, at the same time, to decide to his satisfaction the true amount of displacement of a line in a spectrum of a star due to its motion in the line of sight, had looked with disfavour upon these interesting inquiries as far too difficult and delicate to be practically realised, and had consequently devoted his talents to other, and what at the time might have appeared more fruitful, branches of astronomy, we should not to-day have been able to recognise and admire the brilliant successes which he afterwards accomplished in his various investigations in astronomical physics, by the aid of increased experience and superior instrumental appliances.

And now, gentlemen, I have stated to you in a general manner the principal grounds which have led your Council to award the Medal to Dr. Huggins, and, after the remarks you have heard from me to-day, I am confident that you will coincide with their opinion that the important researches with which he has enriched our science are well deserving of that honour.

The President, then delivering the Medal to Dr. Huggins, addressed him in the following terms :—

Dr. Huggins,—

I have great pleasure in presenting you with this Medal which has been honourably awarded to you by the Council. I trust you will accept it as the highest acknowledgment of your valuable services to our science which it is in their power to bestow. This is not the first time that your devotion to astronomy has been recognised from this Chair, and I hope that it is not the last, for we still find you carrying on with success your important and delicate researches. May your health be long preserved, and may astronomy long continue to receive the benefit of your talents, which I have no doubt will be the means of still further adding to our present knowledge of the constitution of the universe.

The meeting then proceeded to the election of the Officers and Council for the ensuing year, when the following Fellows were elected:—

President.

Edwin Dunkin, Esq., F.R.S.

Vice-Presidents.

J. C. Adams, Esq., M.A., LL.D., D.C.L., F.R.S., Lowndean Professor of Astronomy, Cambridge.
Arthur Cayley, Esq., M.A., LL.D., D.C.L., F.R.S., Sadlerian Professor of Pure Mathematics, Cambridge.
Warren De La Rue, Esq., M.A., Ph.D., D.C.L., F.R.S.
E. J. Stone, Esq., M.A., F.R.S., Radcliffe Observer.

Treasurer.

A. A. Common, Esq.

Secretaries.

E. B. Knobel, Esq.
Lieut.-Col. G. L. Tupman, R.M.A.

Foreign Secretary.

William Huggins, Esq., LL.D., D.C.L., F.R.S.

Council.

Capt. W. de W. Abney, R.E., F.R.S.
Sir G. B. Airy, K.C.B., M.A., LL.D., D.C.L., F.R.S.
J. Rand Capron, Esq.
W. H. M. Christie, Esq., M.A., F.R.S., Astronomer Royal.
A. M. W. Downing, Esq., M.A.
J. W. L. Glaisher, Esq., M.A., F.R.S.
J. R. Hind, Esq., LL.D., F.R.S., Superintendent of the *Nautical Almanac*.
George Knott, Esq., LL.B.
E. W. Maunder, Esq.
Rev. Charles Pritchard, D.D., F.R.S., Savilian Professor Astronomy, Oxford.
A. Cowper Ranyard, Esq., M.A.
Lieut.-Gen. J. F. Tennant, R.E., F.R.S.